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NSWC TECHNICAL REPORT

WHITE OAK LABORATORY

REAL TIME THREE LAYER OCEAN MODEL

BY
P.J. Craun

5 APRIL 1976

NAVAL SURFACE WEAPONS CENTER
WHITE OAK LABORATORY
SILVER SPRING, MARYLAND 20910

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WHITE OAK, SILVER SPRING, MARYLAND 20910

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The simulation of acoustic targets in the ocean environment requires an ocean model which produces realistic propagation effects. This report describes a three layer ocean model which is part of a real time acoustic signal generator which was developed at the Naval Surface Weapons Center, White Oak Laboratory. The ocean model is written in Data General assembly language and runs on a Super Nova minicomputer. Detailed charts

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and listings of the ocean model are included in this report.

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REAL TIME THREE LAYER OCEAN MODEL

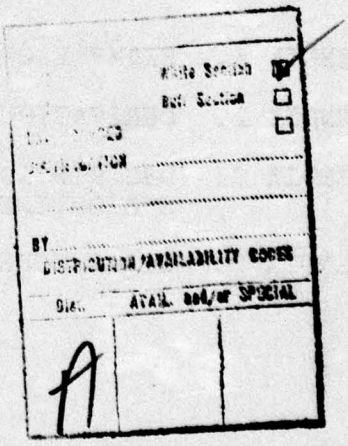
Preface

5 April 1976

This report describes an ocean model which is part of the Acoustic Signal Generator System which was developed at the Naval Surface Weapons Center, White Oak Laboratory. The theoretical approach for this task was originally formulated by Michael D. Stern. The material should be of interest to those involved in acoustic modeling for systems evaluation and training purposes. This work was performed in the Signal and Digital Processing Branch of the Sensors Division and was funded by the Naval Sea Systems Command under the Acoustic Data Repository Task.

Edward C. Whitman

EDWARD C. WHITMAN
By direction



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REAL TIME THREE LAYER OCEAN MODEL

INTRODUCTION

Figure 1 shows the Acoustic Signal Generator System, ASGS, which was developed at the Naval Surface Weapons Center, White Oak Laboratory. It is a multi-minicomputer system which simulates various types of targets such as submarines, surface ships, and torpedoes. Analog signals are generated which correspond to the output of various acoustic receivers or sonobuoys. The system is capable of real time problem generation with two targets and four sonobuoys within a dynamic geometry situation. This requires a real time ocean model to calculate the propagation parameters such as time delays, gains, and angles of arrival for all of the propagation paths that exist between the targets and sensors.

The ASGS ocean model is a ray trace using a three layer ocean with a linear sound velocity profile specified for each of the layers. This model computes all the propagation parameters needed by the ASGS to produce most of the important ocean propagation effects such as shadow zones, multipath interferences, convergence zones, and doppler effects. A Newton-Raphson technique is used by the ocean model to calculate the propagation parameters for the latest target-sonobuoy pair positions starting with the results from their

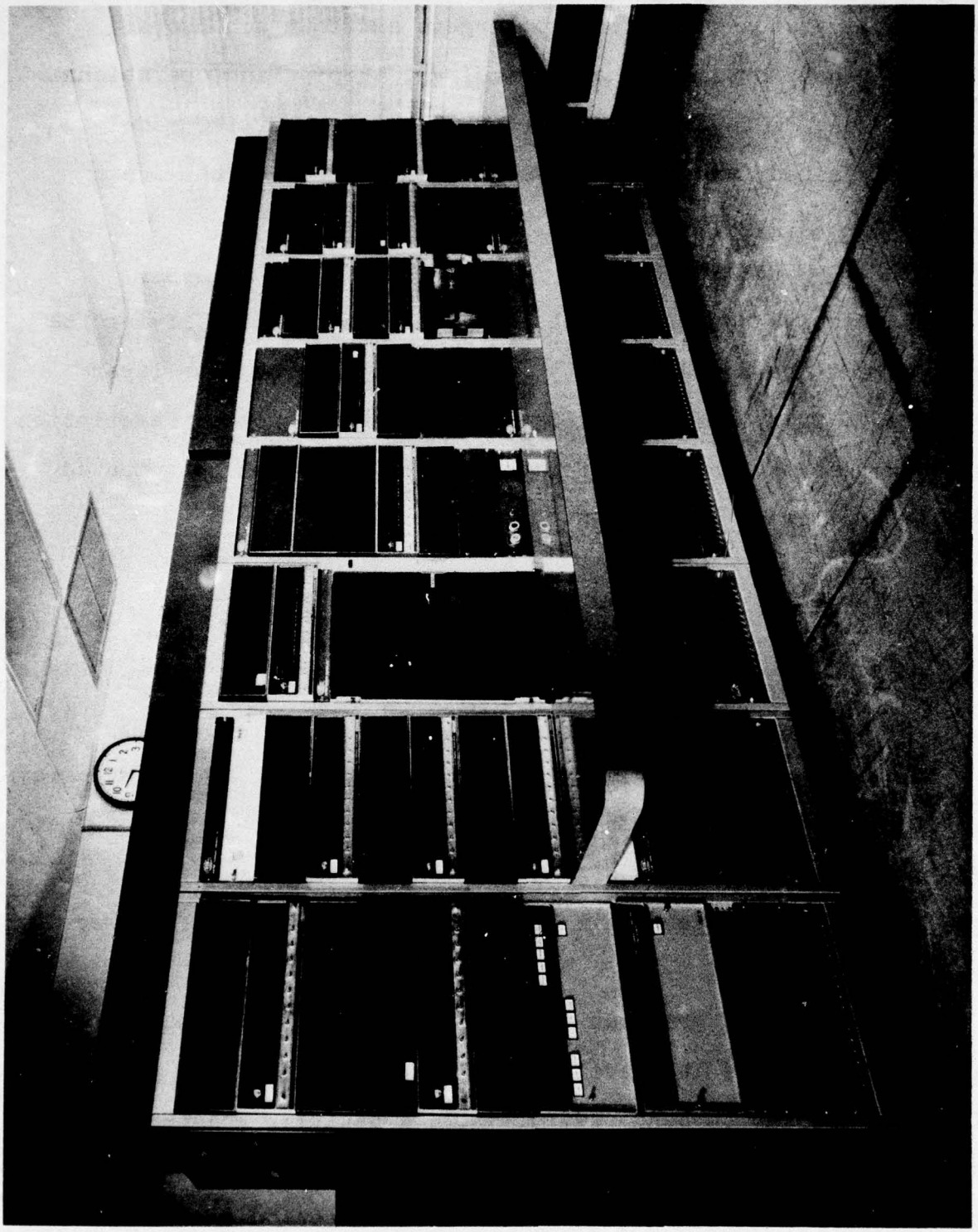


FIG. 1 ACOUSTIC SIGNAL GENERATOR SYSTEM

last positions. This technique allows a solution update rate of approximately two seconds for two targets and four sonobuoys.

This report explains the terminology, theory, and operational details of the ASGS ocean model. Each subroutine of the model is listed, explained, and flow charted,and an example of the ocean model output is presented.

GRADIENTS AND TURNOVER POINTS

A particular three layer ocean is described by specifying the depth, d, and the sound velocity, v, for each of the four layer interfaces. This is shown in Figure 2. From this ocean description the sound velocity gradients for the three layers can be computed using the following expression.

$$g_i = \frac{v_{i-1} - v_i}{d_{i-1} - d_i} \quad ; \quad i = 1, 2, \text{ and } 3 \qquad (1)$$

Since the gradient of each layer is a constant, an acoustic ray traveling through a layer travels a circular arc with a radius that is a function of the value of the gradient in that layer. Ray paths in the three layer ocean are, therefore, made up of connecting circular segments.

The sign of the gradient in a layer determines in what direction the ray will bend as it travels in the layer. A positive gradient will cause the ray to bend upward, while a negative gradient will cause the ray to bend downward. A ray may obtain total reflection within a layer, which means it will change direction inside the

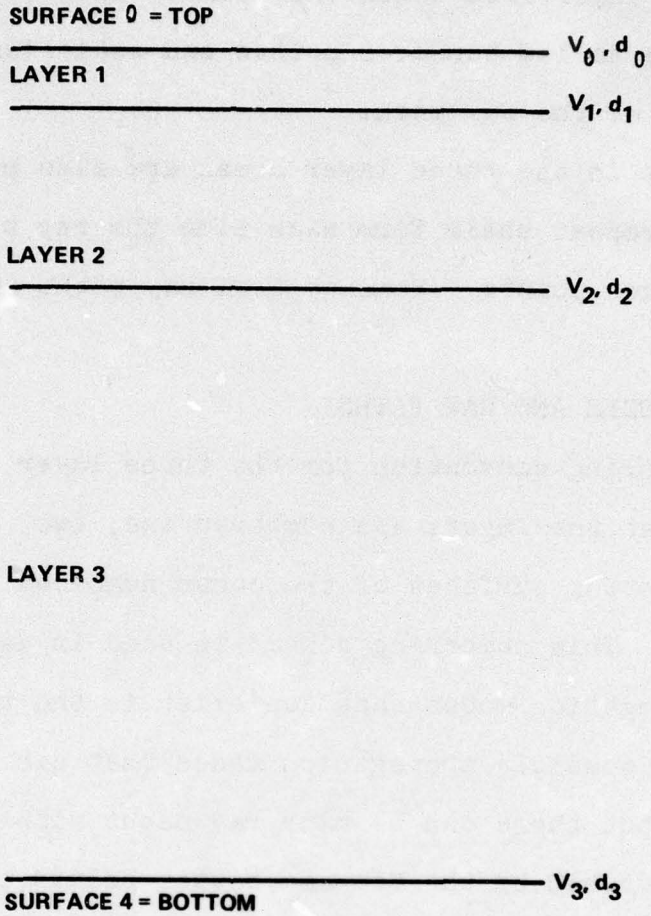


FIG. 2 SPECIFICATION OF THREE LAYER OCEAN

layer and travel back toward the same side that it entered. Rays may also strike the ocean top and bottom surfaces and be reflected back into the layer from which they came. Both of these types of reflection are called turnover points and establish the top and bottom points of the ray path.

Ray paths in the three layer ocean are also periodic in nature because they repeat their form each time the ray travels between sets of turnover points. Some typical ray paths are shown in Figure 3.

PROPAGATION MODES AND RAY PATHS

The numbering convention for the three layer ocean model is defined so that the layers are numbered one, two, and three with the top and bottom surfaces of the ocean numbered zero and four respectively. This numbering scheme is used in defining the acoustic propagation modes that can exist in the three layer ocean. There are ten possible propagation modes that can exist in a three layer ocean, but there can be many ray paths within each mode. A mode is described by the top and bottom points of the ray paths in the mode. The top of the mode, T, is the number of the layer or surface in which the ray paths turn downward. The bottom of the mode, B, is the number of the layer or surface in which the ray paths turn upward. Figure 4 shows examples of all possible propagation modes that can exist in the three layer ocean.

For any particular three layer ocean the consideration of the signs of the gradients in the layers will eliminate some of the ten possible propagation modes that can exist. Further reductions in the number of modes is obtained when the location of a particular

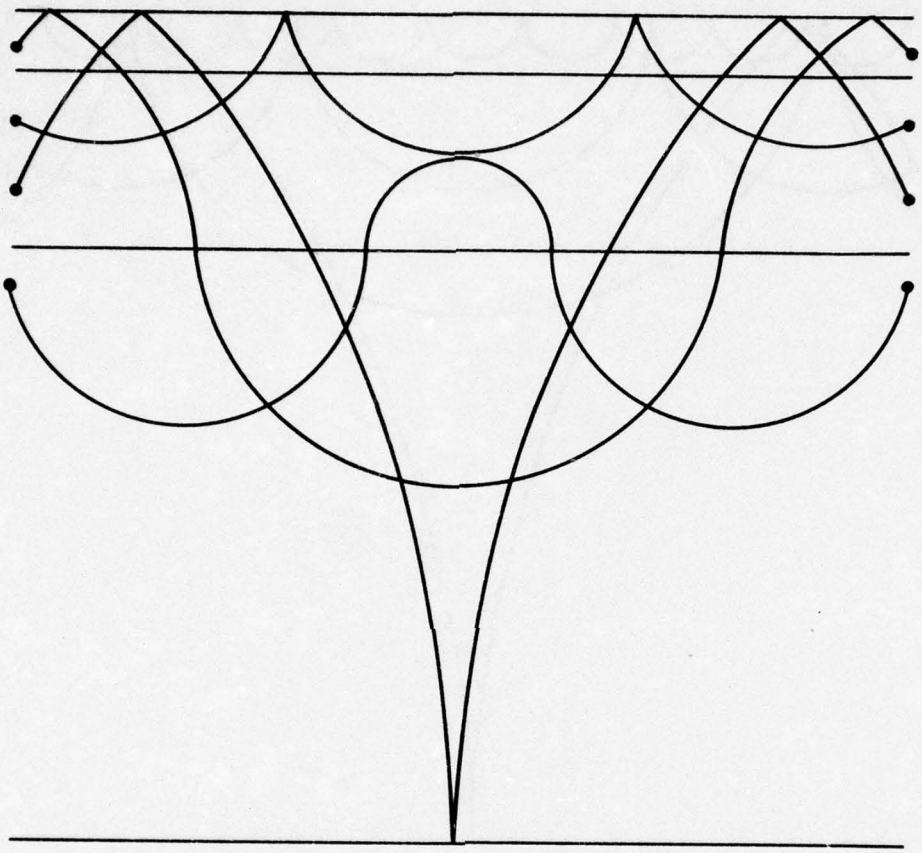


FIG. 3 TYPICAL RAY PATHS WITH TURNOVER POINTS

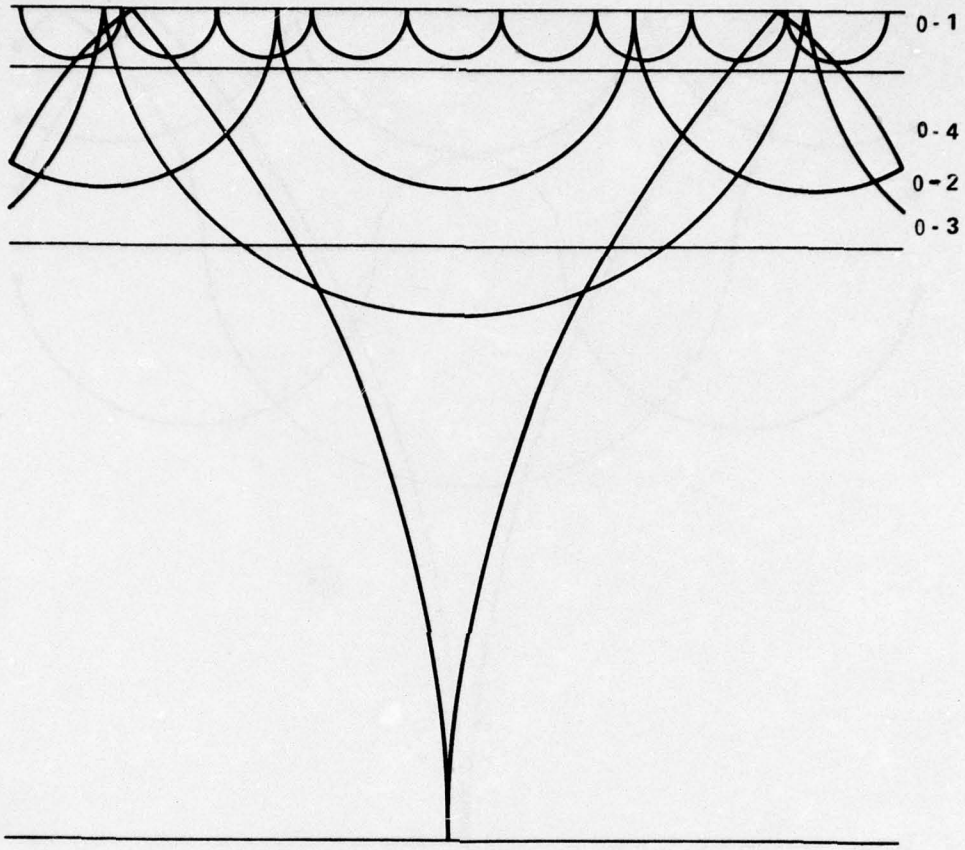
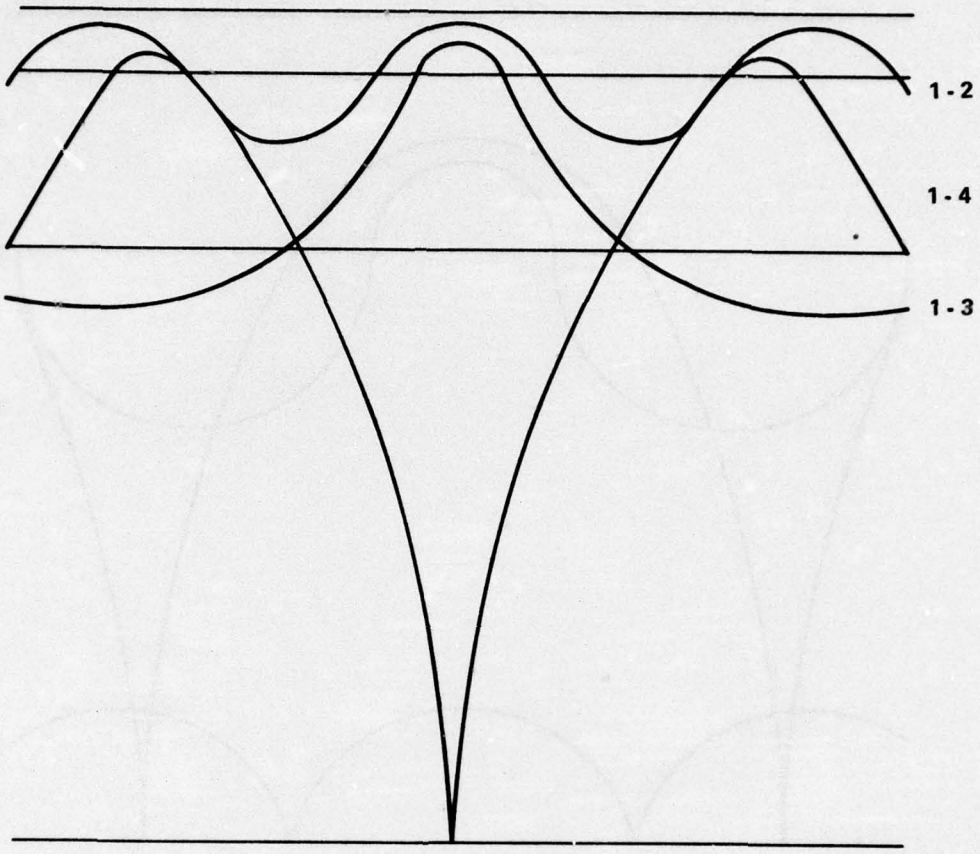


FIG. 4 POSSIBLE PROPAGATION MODES IN THREE LAYER OCEAN



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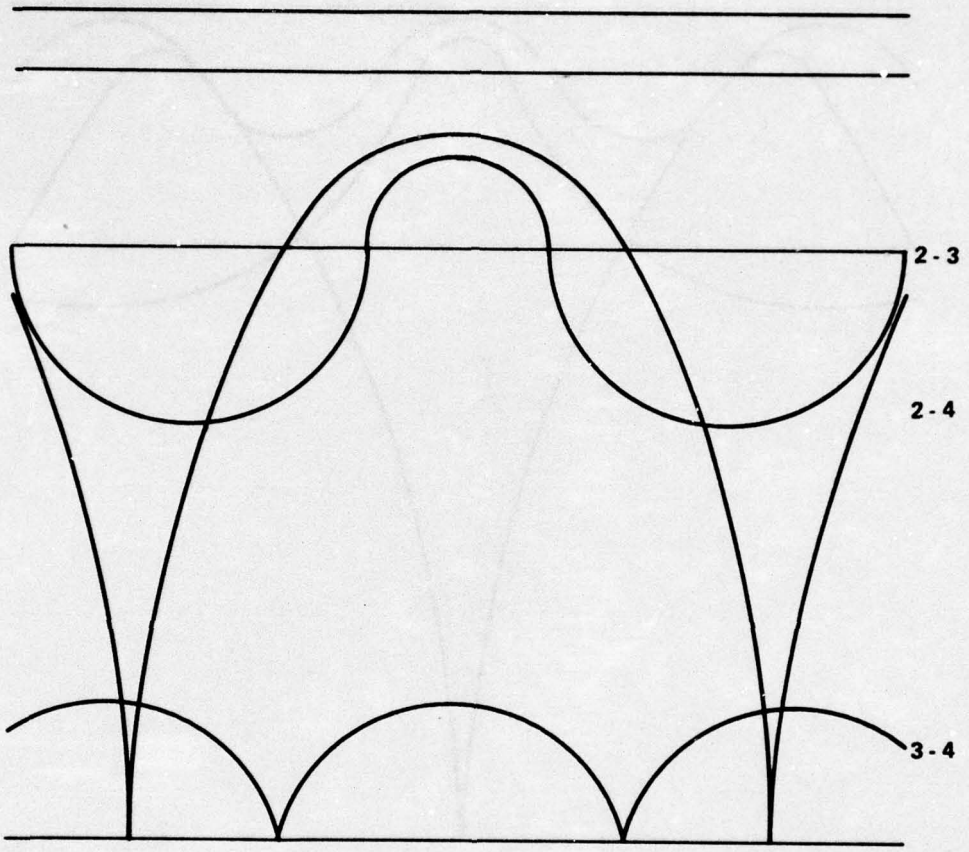


FIG. 4 CONTINUED

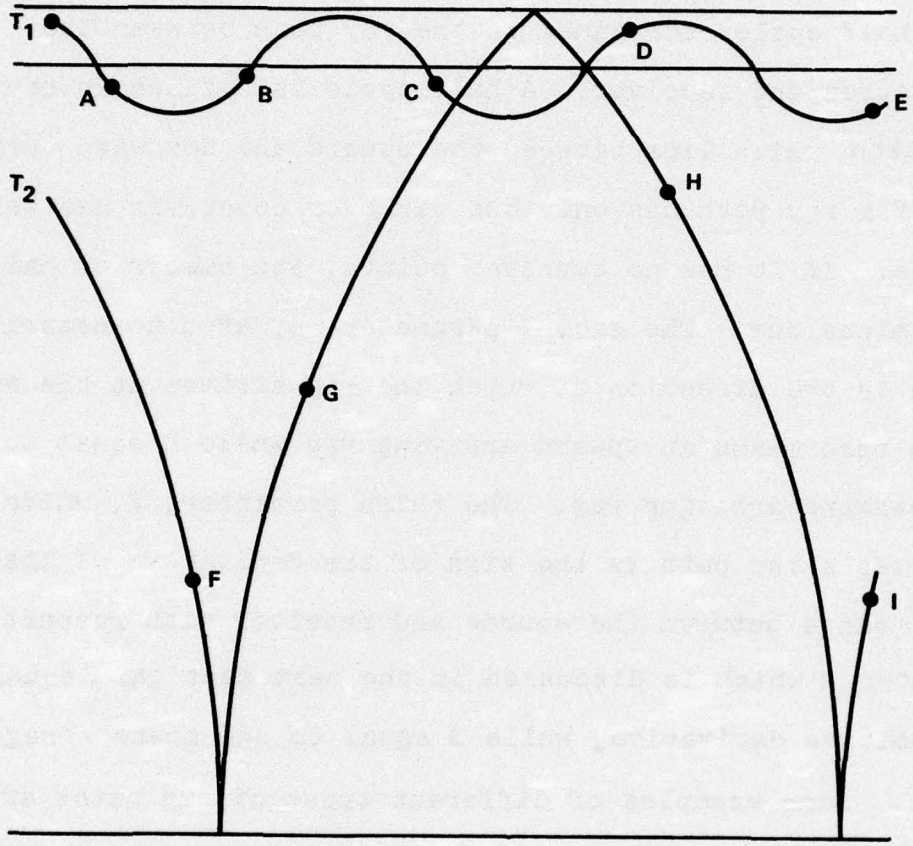
target-sonobuoy pair is considered. An example of determining the possible propagation modes for a particular three layer ocean with a target-sonobuoy pair location is given in Appendix A.

The ray paths within a propagation mode are uniquely characterized by three parameters. The first parameter, N, is the number of half cycles contained in the ray path between the acoustic source and receiver. A half cycle is defined as that part of a ray path which lies between the upward and downward turnover points. If a ray path has only one turnover point, it has zero half cycles. If it has no turnover points, its number of half cycles is minus one. The second parameter, D, used to describe a ray path is the direction at which the ray arrives at the receiver. D equal to zero means an upward arriving ray while D equal to one means a downward arriving ray. The third parameter, S, which characterizes a ray path is the sign of the derivative of its horizontal range between the source and receiver with respect to the parameter z which is discussed in the next section. S equal to zero means a positive derivative, while S equal to one means a negative derivative. Some examples of different types of ray paths are shown in Figure 5.

Z LIMITS AND MINIMUM AND MAXIMUM NUMBER OF HALF CYCLES

For every ray path that connects a target and sonobuoy in the three layer ocean, a constant can be defined which uniquely distinguishes that ray path from any other. This constant is called z and is defined as

$$z = \frac{v_p}{\sin a_p} \tag{2}$$



RAY PATH	T	B	N	D	S
T_1 - A	1	2	-1	1	0
T_1 - B	1	2	0	0	0
T_1 - C	1	2	1	1	0
T_1 - D	1	2	2	0	0
T_1 - E	1	2	4	0	0
T_2 - F	0	4	-1	1	1
T_2 - G	0	4	0	0	1
T_2 - H	0	4	1	1	1
T_2 - I	0	4	2	0	1

FIG. 5 EXAMPLES OF TYPES OF RAY PATHS

where v_p = sound velocity at a point on the ray

a_p = angle that the ray makes with the vertical at the point on the ray path.

Each propagation mode that exists for a particular three layer ocean has limits which bound the value that z can obtain for any ray path in the mode. These limits are based on the fact that a ray with a value of z cannot enter a region for which the sound velocity is greater than that value of z. This maximum value of sound velocity is encountered by a ray at the turnover points where a_p equals ninety degrees and v_p equals z. Examining the layers or surfaces in which these turnover points occur supplies the limits on the value of z. The maximum value of z is the smaller of the following two quantities. The first is the largest sound velocity in the top layer of the propagation mode if the top is a layer or infinity (or a conveniently large value) if the top is a surface. The second is the largest sound velocity in the bottom layer of the propagation mode if the bottom is a layer or infinity (or a conveniently large value) if the bottom is a surface. Finding the minimum value of z is more involved and takes into account the sound velocities encompassed by the propagation mode. The minimum value of z is the larger of the following sound velocities; the smallest sound velocity from the top layer of the propagation mode, the smallest sound velocity from the bottom layer of the propagation mode, the sound velocity at the target depth, the sound velocity at the sonobuoy depth, and the sound velocities of the layer interfaces encompassed by the propagation mode.

After the z limits have been found for a propagation mode, an estimate of the minimum and maximum number of half cycles which can exist for the different ray paths in the mode can be made. Two half

cycle horizontal ranges can be computed from these two z limits using the formulas explained in the next section. Dividing the actual horizontal range that exists between the target and sonobuoy by the two half cycle horizontal ranges results in two values which are the minimum and maximum number of half cycles for the mode. Subtracting one from the minimum number of half cycles will take into account the end parts of the ray path which travel from a turnover point to the target and sonobuoy and are not full half cycles.

THREE LAYER OCEAN MODEL EQUATIONS

The equations used in the calculations for the three layer ocean model are derived in Appendix B. These equations are repeated in this section of the report and then expanded to cover all the parts of a ray path as it travels from the target to the sonobuoy. The three layer ocean model equations are as follows:

Horizontal Range of a Circular Segment of a Ray Through a Layer:

$$HRG = \frac{\sqrt{z^2 - v_{i-1}^2} - \sqrt{z^2 - v_i^2}}{g_i} \tag{3}$$

Slant Range of a Circular Segment of a Ray Through a Layer:

$$SRG = \frac{z}{g_i}\left[\sin^{-1}\left(\frac{v_{i-1}}{z}\right) - \sin^{-1}\left(\frac{v_i}{z}\right)\right] \tag{4}$$

Derivative of HRG with respect to z:

$$\frac{d(HRG)}{dz} = \frac{z}{g_i}\left(\frac{1}{\sqrt{z^2 - v_{i-1}^2}} - \frac{1}{\sqrt{z^2 - v_i^2}}\right) \tag{5}$$

Angle of Arrival of a Ray Path at a Sonobuoy:

$$ANG = \sin^{-1}\left(\frac{v_{sonobuoy}}{z}\right) \tag{6}$$

Time Delay of a Circular Segment of a Ray Through a Layer:

$$TD = \frac{1}{g_i}\left[\ln\left(\frac{v_{i-1}}{z - \sqrt{z^2 - v_{i-1}^2}}\right) - \ln\left(\frac{v_i}{z - \sqrt{z^2 - v_i^2}}\right)\right] \tag{7}$$

Power Gain of a Ray Path at the Sonobuoy:

$$GAIN = \frac{v_{TARGET}^2}{HRG \cdot \frac{d(HRG)}{dz} \cdot z \cdot \sqrt{z^2 - v_{TARGET}^2} \cdot \sqrt{z^2 - v_{SONOBUOY}^2}} \tag{8}$$

Any ray path in the three layer ocean can be decomposed into circular segments of up to three different types. The first type is a segment which travels from one point to another in the same layer without a turnover point. The second type is a segment which travels from one point in a layer to another point in the same layer where one of the points is a downward turnover point. The third type is a segment which travels from one point in a layer to another point in the same layer where one of the points is an upward turnover point. The points described for the three types of segments may be a combination of target position, sonobuoy position, turnover points,

and layer interface points. Examples of these types of segments are given in Figure 6.

Equations 3, 4, 5 and 7 are used directly for the Type 1 circular segment with v_{i-1} and v_i taken at the top and bottom points respectively. The value of i equals the layer number in which the segment is located. The Type 2 circular segment equations are as follows:

$$HRG_2 = -\frac{\sqrt{z^2 - v_i^2}}{g_i} \tag{9}$$

$$SRG_2 = \frac{z}{g_i}\left[-\sin^{-1}\left(\frac{v_i}{z}\right)\right] \tag{10}$$

$$\frac{d(HRG_2)}{dz} = \frac{z}{g_i}\left(\frac{1}{\sqrt{z^2 - v_i^2}}\right) \tag{11}$$

$$TD_2 = \frac{1}{g_i}\left[-\ln\left(\frac{v_i}{z - \sqrt{z^2 - v_i^2}}\right)\right] \tag{12}$$

The Type 3 circular segment equations are as follows:

$$HRG_3 = \frac{\sqrt{z^2 - v_{i-1}^2}}{g_i} \tag{13}$$

$$SRG_3 = \frac{z}{g_i}\left[\sin^{-1}\left(\frac{v_{i-1}}{z}\right)\right] \tag{14}$$

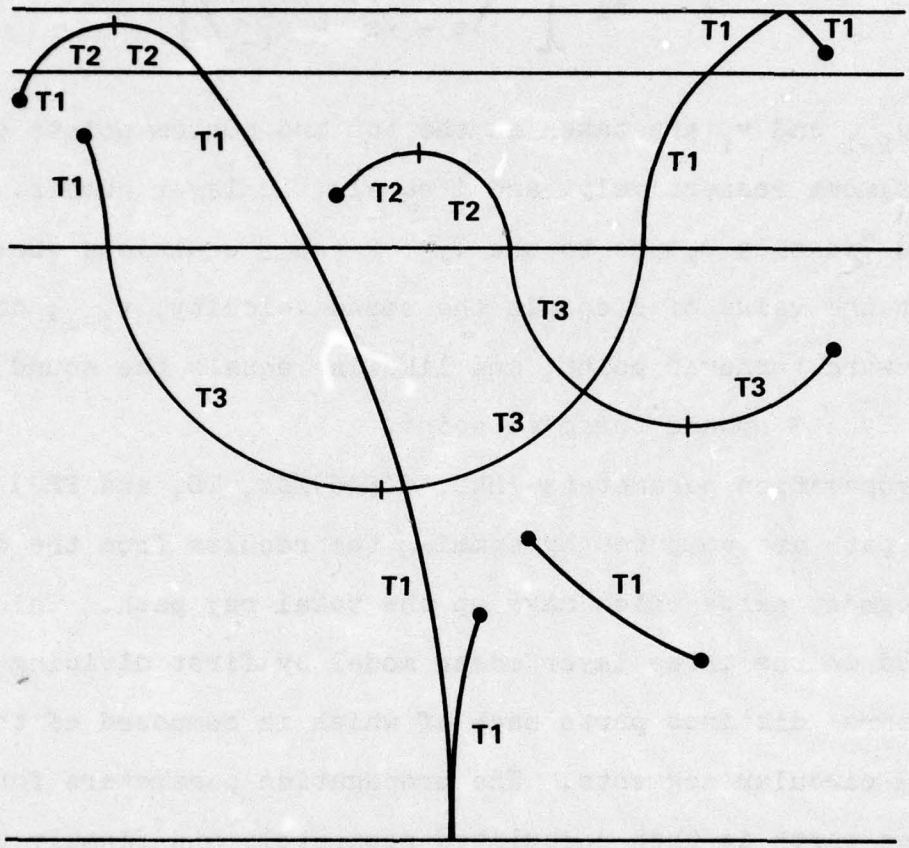


FIG. 6 TYPES OF CIRCULAR SEGMENTS MAKING UP RAY PATHS

$$\frac{d(HRG_3)}{dz} = \frac{z}{g_i} \left(\frac{1}{\sqrt{z^2 - v_{i-1}^2}} \right) \tag{15}$$

$$TD_3 = \frac{1}{g_i} \left[\ln \left(\frac{v_{i-1}}{z - \sqrt{z^2 - v_{i-1}^2}} \right) \right] \tag{16}$$

As before v_{i-1} and v_i are taken at the top and bottom points of the circular segment respectively, and i equals the layer number. Equations 3, 4, 5 and 7 easily reduce to the Type 2 and 3 equations above by noting that the value of z equals the sound velocity, v_{i-1}, at the Type 2 downward turnover point, and likewise equals the sound velocity, v_i, at the Type 3 upward turnover point.

The propagation parameters (HRG, d(HRG)/dz, TD, and SRG) associated with a ray path are computed by summing the results from the different circular segment parts which make up the total ray path. This is accomplished in the three layer ocean model by first dividing the ray path into three distinct parts each of which is composed of the Type 1, 2, and 3 circular segments. The propagation parameters for each of the three parts is then calculated separately and finally combined to arrive at the total parameter values. The first part of the ray path is the C part which is the half cycle portion of the ray path. The second is the A part which is the portion of a half cycle from the top of the ray path to the sonobuoy. The third is the B part which is the portion of a half cycle from the top of the ray path to the target. Multiplying the results from the C part calculations by the number of half cycles in the ray path and then adding on the results of the

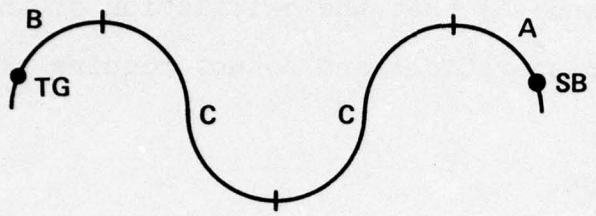
calculations for the A and B parts produces the total ray path propagation parameters. Examples of this procedure are shown in Figure 7. Note from equations (6) and (8) that the calculation of the values of ANG and GAIN are one step operations and do not require the A, B, and C computations.

NEWTON-RAPHSON CALCULATION

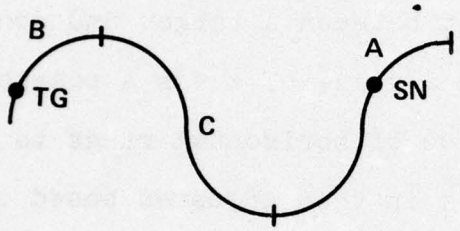
A Newton-Raphson technique is used in the three layer ocean model to find the ray paths which exist between a target and sonobuoy. This is accomplished by starting with a value of z for a possible ray path and comparing the calculated value of horizontal range to the actual horizontal range. The value of z is then adjusted based on the amount of error in horizontal range and the calculated value of the derivative of horizontal range with respect to z. This calculation is expressed as

$$z_{NEW} = z_{OLD} + \frac{(\text{Actual HRG} - \text{Calculated HRG})}{\text{Calculated } \frac{d(\text{HRG})}{dz}} \quad (17)$$

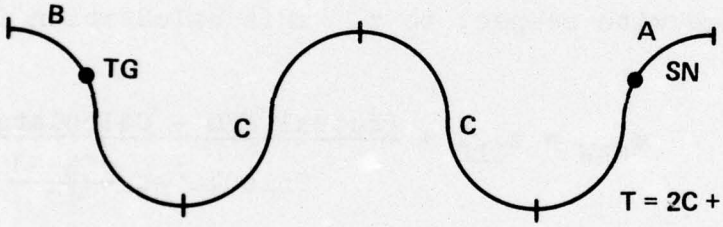
This new value of z can then be used to further reduce the error. This calculation is repeated until the error reaches some allowable value such as $\pm 1/8$ meter. Since the target position does not change appreciably from one pass through the ocean program to the next, the last value of z for a ray path can be saved and used as its starting point for the Newton-Raphson calculation. Only a few loops through the calculation are required to meet the allowable error. New ray paths which did not exist on the preceding pass through the ocean programs must start with the values of the z limits for the Newton-Raphson calculation, which may require many loops to achieve the allowable error in horizontal range.



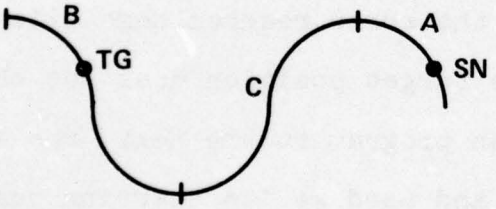
$T = 2C + A + B$



$T = C + B + (C - A)$



$T = 2C + (C - A) + (C - B)$



$T = C + A + (C - B)$

FIG. 7 TOTAL RAY PATH COMPOSITION AND CALCULATION

During the Newton-Raphson calculation there are three tests that the value of z for the ray path must pass to remain a valid solution. The first is that the value of z for the ray path must not exceed the maximum z limit. The second test is that the value of z must not equal or go below the minimum z limit. The third test is that the sign of the derivative of the horizontal range of the ray path with respect to z must not change sign.

RAY PATH CODE WORDS

Sixteen bit code words are used in the three layer ocean model to represent the ray paths and save core memory space. The following convention is followed for a code word:

BITS	DATA	DATA RANGE
0 through 2	T	0 to 3
3 through 5	B	1 to 4
6	D	0 to 1
7 through 14	N	-1 to 127
15	S	0 or 1

All of the three layer ocean model equations can be calculated for a ray path given its code word and value of z.

GENERAL PROGRAM OPERATION

The three layer ocean model operates using the following general steps:

1. Compute the gradients of the three layers if any of the sound velocities at the layer interfaces have changed.
2. Find the possible propagation modes for the particular target-sonobuoy pair that is being considered.

3. Find the limits on the value of z for each of the possible propagation modes.
4. Compute the minimum and maximum number of half cycles for each of the possible propagation modes.
5. Form a table containing a code word and address of the z limits for each ray path that may exist. This table is designated the TSPCW table and is explained further in Appendix C.
6. Using the Newton-Raphson calculation compute the propagation parameters for all the valid entries in a table which contains a code word and z value for every ray path that produced a valid solution on the last pass through the program. This table is designated the mnLPW table and is explained further in Appendix C.
7. Compute the propagation parameters for all the entries in the TSPCW table which were not also included in the mnLPW table. This computation also uses the Newton-Raphson calculation but it starts from the z limit values. Valid solutions are stored in the mnLPW table with their values of z for use on the next pass through the programs.
8. Examine the propagation gains for all the valid solutions during steps 7 and 8 and store the sixteen greatest gain ray paths in a table with the rest of their propagation parameters. This table is designated the mlBST table and is further explained in Appendix C.

THREE LAYER OCEAN MODEL SUBROUTINES

The three layer ocean model consists of a number of subroutines written for the Data General Super Nova minicomputer. All of the subroutines are programmed in assembly language because of the real time constraint on the ASGS problem generation. Figure 8 shows the

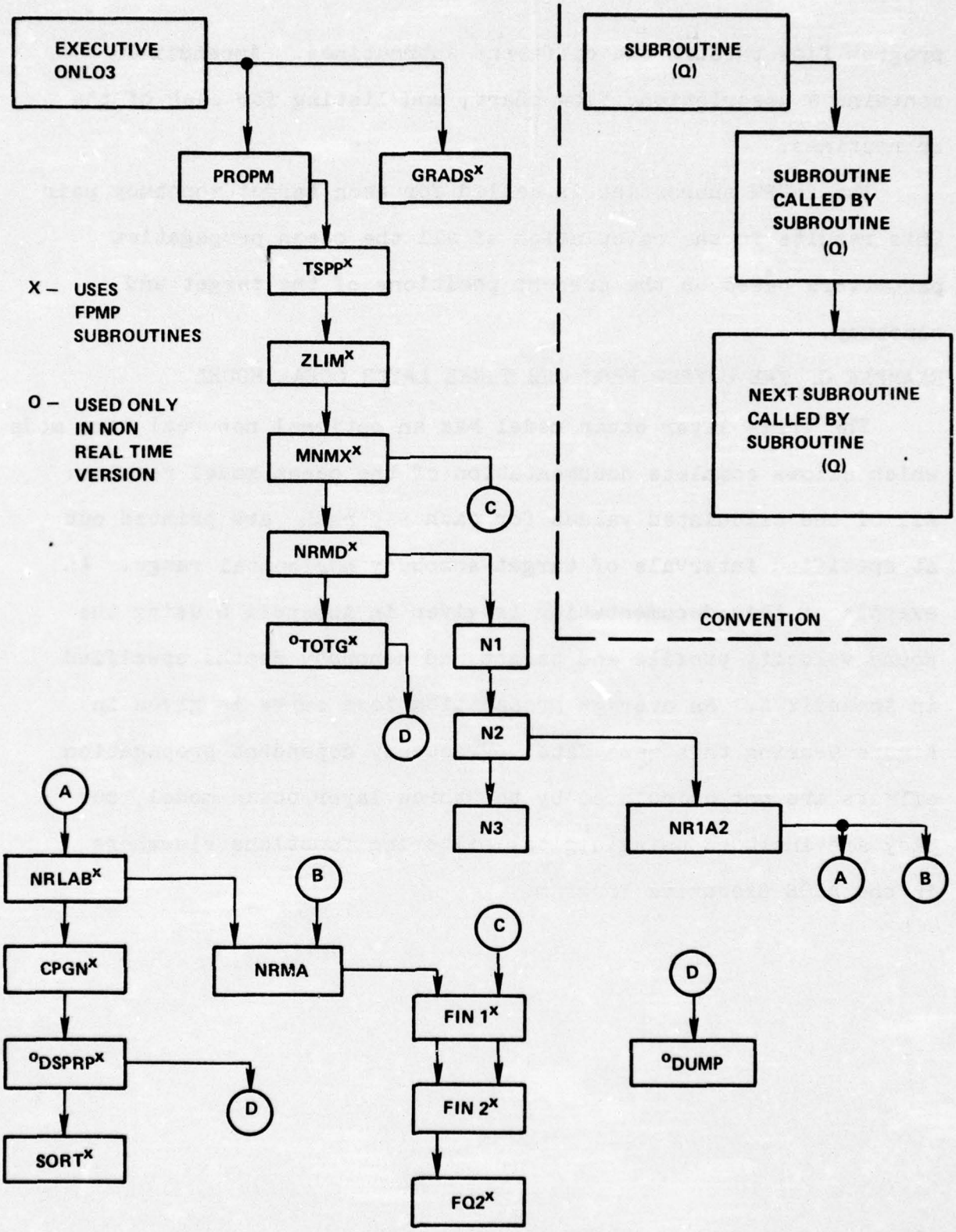


FIG. 8 PROGRAM FLOW

program flow through the different subroutines. Appendix C contains a description, flow chart, and listing for each of the subroutines.

The PROPM subroutine is called for each target-sonobuoy pair This results in the calculation of all the ocean propagation parameters based on the present positions of the target and sonobuoy.

EXAMPLE OF THE OUTPUT FROM THE THREE LAYER OCEAN MODEL

The three layer ocean model has an optional non real time mode which allows complete documentation of the ocean model results. All of the calculated values for each ray path are printed out at specified intervals of target-sonobuoy horizontal range. An example of this documentation is given in Appendix D using the sound velocity profile and target and sonobuoy depths specified in Appendix A. An average propagation loss curve is given in Figure 9 using this same data. Frequency dependent propagation effects are not calculated by the three layer ocean model, but they are included using digital filtering functions elsewhere in the ASGS Executive Program.

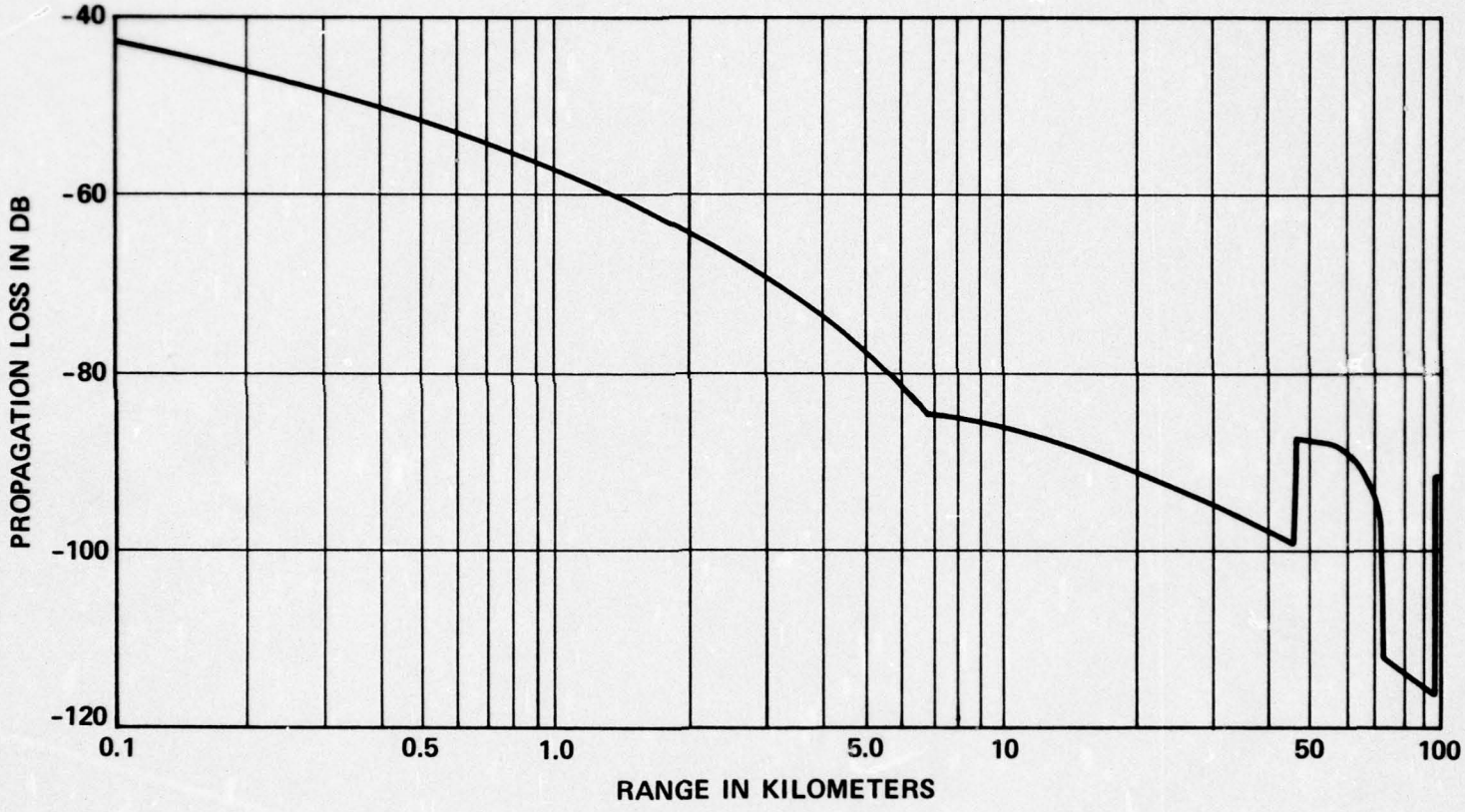


FIG. 9 AVERAGE PROPAGATION LOSS CURVE

APPENDIX A

EXAMPLE OF CALCULATING PROPAGATION MODES

The following depths and sound velocities are given for a three layer ocean.

d_0 = 0 meters

d_1 = 100 meters

d_2 = 500 meters

d_3 = 4000 meters

v_0 = 1490 meters/sec

v_1 = 1496 meters/sec

v_2 = 1486 meters/sec

v_3 = 1520 meters/sec

The target depth is 200 meters, which places it in the second layer. The sonobuoy depth is 50 meters, which places it in the first layer. The gradients are computed using Equation (1) to be the following values:

g_1 = +.06

g_2 = -.025

g_3 = +.0097

Since the ocean surface and the negative gradient second layer cause downward turnover points, the possible tops of modes are 0 and 2.

Since the ocean bottom and the positive gradient first and third layers cause upward turnover points, the possible bottoms of modes are 1, 3 and 4. Combining these tops and bottoms with the obvious restrictions that a top number must be smaller than a bottom number gives the following possible propagation modes in the form of (T, B).

Mode 1 = (0, 1)

Mode 2 = (0, 3)

Mode 3 = (0, 4)

Mode 4 = (2, 3)

Mode 5 = (2, 4)

Now considering the target and sonobuoy locations, Modes 1, 4 and 5 can be eliminated because those modes do not encompass both the target and sonobuoy and could not contain a ray path between them. This procedure has reduced the number of possible propagation modes from ten to five and finally to two.

APPENDIX B

DERIVATION OF THREE LAYER OCEAN MODEL EQUATIONS

General Conventions and Relationships

Figure B1 shows an acoustic ray passing through a layer with a constant sound velocity gradient. The ray enters at point P_1 and leaves at point P_2. The coordinates which uniquely describe these two points are

$$P_1 = F(x_1, y_1, v_1, t_1, a_1)$$

$$P_2 = F(x_2, y_2, v_2, t_2, a_2)$$

where x and y are the position, v the sound velocity, t the time, and a the angle that the ray makes with the vertical. The ray passing through points P_1 and P_2 is also uniquely described by the relationship

$$z = \frac{v}{\sin a} \tag{B.1}$$

where z is a constant for any point on the ray.

The sound velocity gradient of the layer through which the ray passes is a constant given by

$$g = \frac{dv}{dy} = \frac{v_1 - v_2}{d_1 - d_2} \tag{B.2}$$

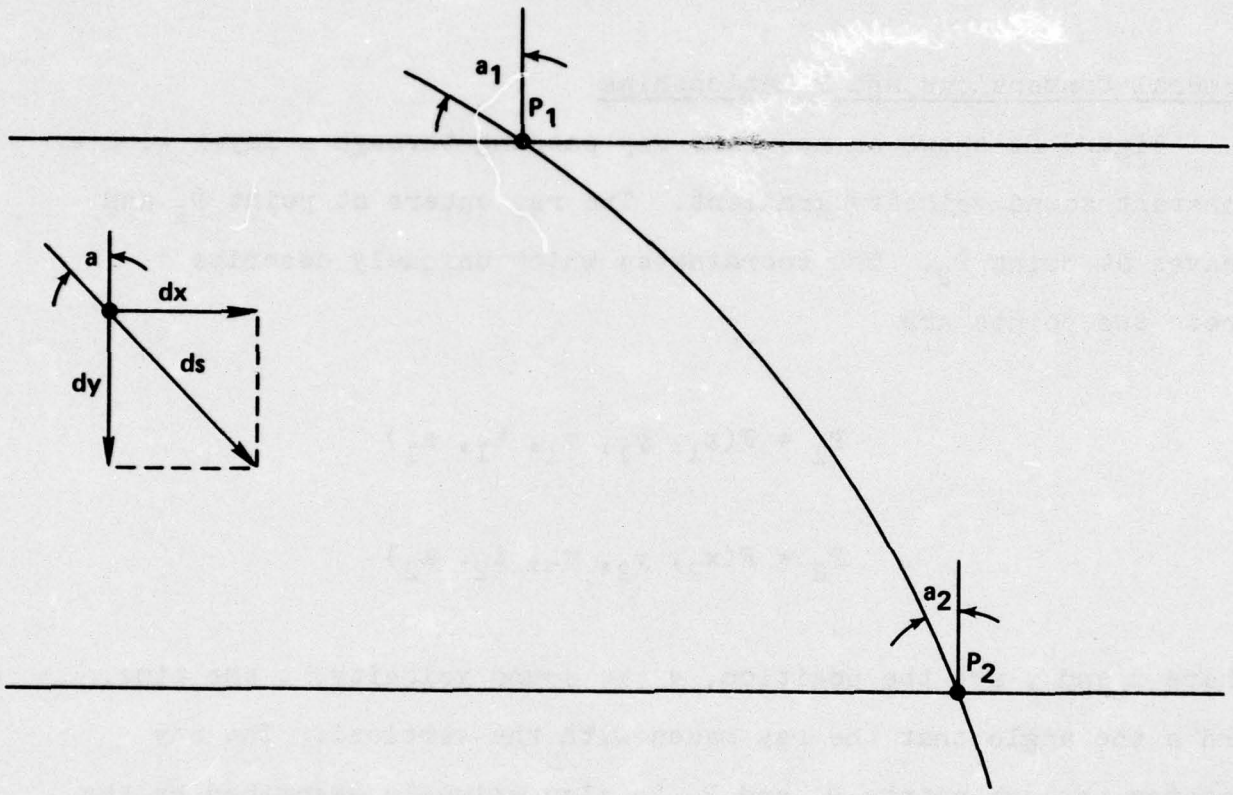


FIG. B1 RAY PATH PASSING THROUGH A LAYER

Other important relationships that are useful are derived by examining the differential part of the ray in Figure B1. These are expressed as:

$$\cot a = \frac{dy}{dx} \tag{B.3}$$

$$dS = \sqrt{(dx)^2 + (dy)^2} \tag{B.4}$$

The following trigonmetric relationship is also needed in the later derivations.

$$\cos a = \sqrt{1 - \sin^2 a}$$

Substituting using Equation (B.1) yields

$$\cos a = \sqrt{1 - \left(\frac{v}{z}\right)^2}$$

which can be expressed as

$$\cos a = \frac{\sqrt{z^2 - v^2}}{z} \tag{B.5}$$

Horizontal Range

This section derives the expression for the horizontal range traveled by a ray as it passes through a layer with a constant sound velocity gradient. This ray is shown in Figure B1 as entering at point P_1 and leaving at point P_2. The horizontal range is taken in the x direction and is expressed as

$$HRG = \int_{x_1}^{x_2} d_x$$

Substituting using Equation (B.3) yields

$$HRG = \int_{y_1}^{y_2} \left(\frac{1}{\cot a}\right) dy \qquad (B.6)$$

Differentiating Equation (B.1) leads to the following useful relationship

$$d\ (\sin a) = \frac{dv}{z}$$

$$\cos a \cdot da = \frac{dv}{z} \qquad (B.7)$$

Substituting Equations (B.2) and (B.7) into Equation (B.6) allows the horizontal range to be expressed as

$$HRG = \int_{a_1}^{a_2} \left(\frac{z \cdot \cos a}{g \cdot \cot a}\right) \cdot da \qquad (B.8)$$

which reduces to

$$HRG = \int_{a_1}^{a_2} \frac{z}{g} \sin a \cdot da \qquad (B.9)$$

Integrating Equation (B.9) yields

$$HRG = -\frac{z}{g}(\cos a_2 - \cos a_1) \tag{B.10}$$

which reduces to a more convenient form using Equation (B.5)

$$HRG = \frac{\sqrt{z^2 - v_1^2} - \sqrt{z^2 - v_2^2}}{g} \tag{B.11}$$

Derivative of Horizontal Range with Respect to z

The derivative of the horizontal range with respect to z is used in the ray path calculations. Differentiating Equation (B.11) with respect to z yields the following

$$\frac{d(HRG)}{dz} = \frac{z}{g}\left(\frac{1}{\sqrt{z^2 - v_1^2}} - \frac{1}{\sqrt{z^2 - v_2^2}}\right) \tag{B.12}$$

Time Delay

The time delay that a ray experiences as it passes through a layer is the next quantity to be derived. The following differential equation expresses the sound velocity at a point.

$$v = \frac{ds}{dt} \tag{B.13}$$

Using Equations (B.4) and (B.13) produces the differential equation for the time delay.

$$dt = \frac{\sqrt{dx^2 + dy^2}}{v} \tag{B.14}$$

$$dt = \frac{\sqrt{dy^2\left(1 + \frac{dx^2}{dy^2}\right)}}{v}$$

which becomes using Equation (3)

$$dt = \frac{dy}{v}\sqrt{1 + \left(\frac{1}{\cot a}\right)^2}$$

This then reduces to

$$dt = \frac{dy}{v \cdot \cos a} \tag{B.15}$$

using trigonmetric identities.
Substituting Equations (B.1), (B.2), and (B.7) into Equation (B.15) produces the following expression.

$$dt = \frac{1}{\sin a \cdot g} \cdot da \tag{B.16}$$

Using the following steps to integrate Equation (B.16) yields the desired time delay.

$$t = \int_{t_1}^{t_2} dt = \int_{a_1}^{a_2} \frac{1}{\sin a \cdot g} \cdot da$$

$$t = \frac{1}{g} \cdot \left| \ln (\csc a - \cot a) \right|_{a_1}^{a_2}$$

$$t = \frac{1}{g} \cdot \left| \ln \left(\frac{1 - \cos a}{\sin a}\right) \right|_{a_1}^{a_2}$$

$$t = \frac{1}{g}\left[\ln\left(\frac{1 - \cos a_2}{\sin a_2}\right) - \ln\left(\frac{1 - \cos a_1}{\sin a_1}\right)\right] \qquad \text{(B.17)}$$

Substituting Equations (B.1) and (B.5) into Equation (B.17) and then rearranging terms yields the final form of the expression for the time delay.

$$t = \frac{1}{g}\left[\ln\left(\frac{v_1}{z - \sqrt{z^2 - v_1^2}}\right) - \ln\left(\frac{v_2}{z - \sqrt{z^2 - v_2^2}}\right)\right] \qquad \text{(B.18)}$$

Circular Relationship

This section shows that the ray path travels a circular path in a layer with a constant sound velocity gradient. For convenience the point P_1 can be taken as the point (0, 0) and point P_2 as point (x, y). Equation (B.2) then reduces to

$$g = \frac{v_1 - v_2}{-y}$$

This can then be rearranged into the following form

$$v_2 = v_1 + g \cdot y \qquad \text{(B.19)}$$

Substituting Equation (B.19) into Equation (B.11) yields

$$x = \frac{1}{g}\left(\sqrt{z^2 - v_1^2} - \sqrt{z^2 - (v_1 + g \cdot y)^2}\right) \qquad \text{(B.20)}$$

Rearranging terms and squaring the results produces

$$\left(x - \frac{\sqrt{z^2 - v_1^2}}{g} \right)^2 = \frac{z^2}{g^2} - \left(y + \frac{v_1}{g}\right)^2 \qquad \text{(B.21)}$$

Equation (B.21) is a circle with the following values

$$R = \frac{z}{g} \qquad \text{(B.22)}$$

$$x_o = \frac{\sqrt{z^2 - v_1^2}}{g} \qquad \text{(B.23)}$$

$$y_o = -\frac{v_1}{g} \qquad \text{(B.24)}$$

where R is the radius and point (x_o, y_o) is the center of the circle.

Slant Range

The slant range of the ray traveling through the layer is easily expressed since it is the arc of a circle.

$$SLRG = R(a_1 - a_2) \qquad \text{(B.25)}$$

Substituting with Equation (B.22) and the inverse of Equation (B.1) then yields the final form for the slant range expression.

$$SLRG = \frac{z}{g}\left(\sin^{-1}\left(\frac{v_1}{z}\right) - \sin^{-1}\left(\frac{v_2}{z}\right)\right) \qquad \text{(B.26)}$$

Intensity

Figure B2 is used to illustrate the intensity calculation. The intensity at the receiver is related to the intensity at the source by the inverse ratio of the two areas subtended by the two rays that pass through points A and B. This is expressed as

$$\frac{I_R}{I_S} = \frac{dA_S}{dA_R} \tag{B.27}$$

The incremental area of the circular segment subtended by the two rays around point A is expressed as

$$dA_S = 2\pi \cdot \rho_o \cdot r_o \cdot da_S \tag{B.28}$$

Substituting for ρ_o yields

$$dA_S = 2\pi \cdot r_o^2 \cdot \sin a_S \cdot da_S \tag{B.29}$$

The circular area formed by these two rays at point B is expressed as

$$dA_R = 2\pi \cdot r \cdot dh \tag{B.30}$$

where r is the horizontal range. Substituting for dh yields

$$dA_R = 2\pi \cdot r \cdot \cos a_R \cdot dr \tag{B.31}$$

which can be rewritten as

$$dA_R = 2\pi \cdot r \cdot \cos a_R \cdot \left| \frac{dr}{da_S} \right| \tag{B.32}$$

The derivative $\frac{dr}{da_S}$ can be further expanded into

$$\left| \frac{dr}{da_S} \right| = \left| \frac{dr}{dz} \right| \cdot \left| \frac{dz}{da_S} \right| \tag{B.33}$$

Differentiating Equation (B.1) with respect to v produces

$$d(\sin a_S) = \frac{-v_S}{z^2} \, dz \tag{B.34}$$

which equals

$$\cos a_S \cdot da_S = \frac{-v_S}{z^2} \, dz \tag{B.35}$$

Rearranging terms yields

$$\frac{dz}{da_S} = \frac{-z^2 \cdot \cos a_S}{v_S} \tag{B.36}$$

Therefore Equation (B.33) becomes

$$\frac{dr}{da_S} = \left| \frac{dr}{dz} \right| \cdot \frac{z^2 \cdot \cos a_S}{v_S} \tag{B.37}$$

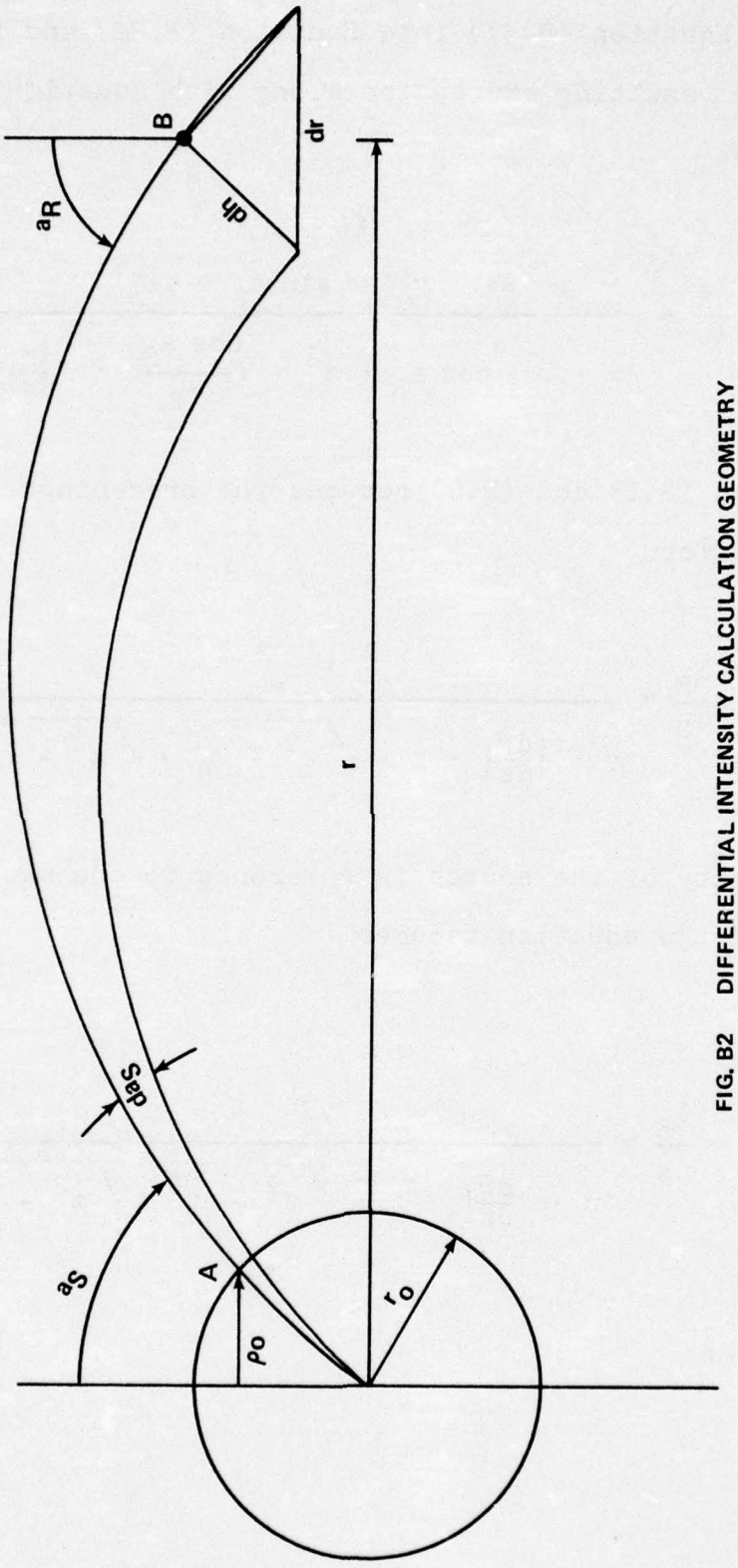


FIG. B2 DIFFERENTIAL INTENSITY CALCULATION GEOMETRY

Substituting Equation (B.37) into Equation (B.32) and then substituting the resulting expression along with Equation (B.29) into (B.27) yields

$$\frac{I_R}{I_S} = \frac{2\pi \cdot r_o^2 \cdot \sin a_S \cdot da_S}{2\pi \cdot r \cdot \cos a_R \cdot z^2 \cdot \left(\frac{\cos a_S}{v_S}\right) \cdot \left|\frac{dr}{dz}\right|} \qquad \text{(B.38)}$$

Using Equation (B.1) and (B.5) reduces the preceding equation to the following form

$$\frac{I_R}{I_S} = \frac{r_o^2 \cdot v_s^2}{r \cdot \left|\frac{dr}{dz}\right| \cdot z \cdot \sqrt{z^2 - v_R^2} \cdot \sqrt{z^2 - v_S^2}} \qquad \text{(B.39)}$$

If the intensity of the source is referenced to one meter, then the final form of the equation becomes

$$\frac{I_R}{I_S} = \frac{v_S^2}{r \cdot \left|\frac{dr}{dz}\right| \cdot z \cdot \sqrt{z^2 - v_R^2} \cdot \sqrt{z^2 - v_S^2}} \qquad \text{(B.40)}$$

APPENDIX C

DESCRIPTIONS, FLOWCHARTS, AND LISTINGS OF SUBROUTINES

The descriptions of the subroutines used in the three layer ocean model are standarized into the form shown in Table C1. The data used in the descriptions, flow charts, and listings of the subroutines in Sections C1 through C22 of this appendix are consistent to allow easy examination and understanding of the ocean model operation. A list of the data used in the subroutines is given in Table C2.

TABLE C1

1. PURPOSE OF THIS SUBROUTINE

2. PROGRAMS THAT CALL THIS SUBROUTINE

3. SUBROUTINE CALLING SEQUENCE

4. OTHER SUBROUTINES CALLED BY THIS SUBROUTINE

5. DATA USED BY THIS SUBROUTINE

6. DATA COMPUTED BY THIS SUBROUTINE

7. FLOW CHART

8. LISTING

9. IMPLEMENTATION NOTES

TABLE C2

List of Data

ACNS1 - Fractional part of the bottom loss which is not a function of the angle that the ray path makes with the bottom.

ADV1 - Calculated value of the derivative of the horizontal range with respect to z for that part of a half cycle of a ray path from the top of the half cycle to the sonobuoy.

ANAR1 - Sine of the angle of arrival of the ray path at the sonobuoy.

ARG1 - Calculated value of the horizontal range for that part of a half cycle of a ray path from the top of the half cycle to the sonobuoy.

ATM1 - Calculated value of the time delay for that part of a half cycle of a ray path from the top of the half cycle to the sonobuoy.

A1CW - Table which contains a ray path partial code word and the address of its z limits in A1Z1 for each mode in A1PP.

A1HR - Actual horizontal range between the target and sonobuoy.

A1MM - Table which contains the minimum and maximum number of ray path half cycles that can exist between the target and sonobuoy for each mode in A1PP.

A1PCT - Number of modes in A1PP.

A1PP - Table which contains the same data as UDGDT minus the propagation modes eliminated by the TSPP and ZLIM subroutines.

TABLE C2 (Cont.)

A1ZL - Table which contains the minimum and maximum limits which bound the value of z for each propagation mode in A1PP.

BBMXF - Flag which shows that a ray path exceeded its maximum z limit.

BCNS1 - Fractional amount of bottom loss which is multiplied by a function of the angle that the ray makes as it strikes the bottom.

BDV1 - Calculated value of the derivative of the horizontal range with respect to z for that part of a half cycle of a ray path from the top of the half cycle to the target.

BGDAT - First word in the central data base of the NRMD subroutine.

BMBFG - Flag which shows that a ray path went below its minimum z limit.

BOMFG - Flag which shows that a ray path solution is invalid.

BRG1 - Calculated value of the horizontal range for that part of a half cycle of a ray path from the top of the half cycle to the target.

BTAN1 - Sine of the angle of arrival of the ray path as it strikes the bottom of the ocean.

BTM1 - Calculated value of the time delay for that part of a half cycle of a ray path from the top of the half cycle to the target.

BTNUM - Number of the layer or surface in which the ray path being calculated turns upward.

TABLE C2 (Cont.)

CDV1 - Calculated value of the derivative of the horizontal range with respect to z for a half cycle part of a ray path.

CODEW - Code word for the particular ray path being calculated.

CRG1 - Calculated value of the horizontal range for a half cycle part of a ray path.

CTM1 - Calculated value of the time delay for a half cycle part of a ray path.

DIRMD - Direction at which the ray path being calculated arrives at the sonobuoy. A zero value means upward; a one value means downward.

DLRG1 - The amount of error between the calculated and actual horizontal range which causes the Newton-Raphson calculation to end.

DVBBF - Flag which shows that the sign of the derivative of the horizontal range with respect to z has changed.

DVP - Derivative of the horizontal range with respect to z intermediate computation table formed by the FIN1 subroutine.

FDV1 - Corrected value of TDV1 which eliminates the calculation of zero derivatives and false caustic errors.

FN1SK - Flag which is set to a one when the A and B parts of a half cycle are to be computed along with the C part.

FN2SK - Flag which is set to a one when the calculation of the ray path time delay is to be included along with that of the horizontal range and its derivative.

TABLE C2 (Cont.)

FUDGE - A quantity which is used to calculate FDV1 based on the value of TDV1.

GAIN1 - Propagation gain (voltage gain) of a ray path for a value of z.

GDTBL - Table which contains the sound velocity gradients of the three layer ocean.

HRRH1 - Actual horizontal range between the target and sonobuoy.

LYDPP - Table which contains the depths of the layer interfaces of the three layer ocean.

LYVEL - Table which contains the sound velocities at the layer interfaces of the three layer ocean.

mnBMS - Table which contains addresses of locations in mnLPW which are vacant and ready for new ray path information.

mnLPW - Table which contains a code word and z value for each ray path that existed between the target and sonobuoy on its preceding pass through the three layer ocean subroutines.

mnNBM - Number of addresses in mnBMS.

mnNLP - Number of valid code words in mnLPW.

m1BST - Table which contains the following information for each of the strongest ray paths that exist between the target and sonobuoy: Code word, time delay, gain, angle of arrival, horizontal range, address of z limits, and z value.

TABLE C2 (Cont.)

m1NBS - Number of ray paths in m1BST.

MAXL1 - Maximum value of z which is used in the standard calculations. Beyond MAXL1, approximations are used in the FIN1 subroutine.

NONRL - Number of Newton-Raphson calculation loops yet to be completed.

NUMCY - Number of half cycles for the ray path being calculated.

RGP - Horizontal range intermediate computation table formed by the FIN1 subroutine.

SDVP - Sonobuoy horizontal range derivative intermediate computation formed by the FIN1 subroutine.

SGNDV - Sign of the derivative of the horizontal range with respect to z for the ray path being calculated.

SLYA - Number of the ocean layer in which the target is located.

SLY1 - Number of the ocean layer in which the sonobuoy is located.

SNSQ1 - Square of the sound velocity at the sonobuoy.

.SnXH - Sonobuoy n's position (X, Y, Z).

SRGP - Sonobuoy horizontal range intermediate computation formed by the FIN1 subroutine.

STMP - Sonobuoy time delay intermediate computation formed by the FIN1 subroutine.

SVLA - Sound velocity at the target.

SVL1 - Sound velocity at the sonobuoy.

TDVP - Target horizontal range derivative intermediate computation formed by the FIN1 subroutine.

TABLE C2 (Cont.)

TDV1 - Calculated value of the derivative of the horizontal range with respect to z for a value of z for a ray path.

TGSQ1 - Square of the sound velocity at the target.

TMP - Time delay intermediate computation table formed by the FIN1 subroutine.

.TmXH - Target m's position (X, Y, Z).

TPNUM - Number of the layer or surface in which the ray path being calculated turns downward.

TRGP - Target horizontal range intermediate computation formed by the FIN1 subroutine.

TRG1 - Calculated value of horizontal range for a value of z for a ray path.

TSIBS - Table which contains the same information as m1BST. It is used as a working buffer area with its final results being transferred into A1BST or B1BST depending on which target is being considered at that time.

TSNIB - Number of ray path solutions in TSIBS.

TSNPW - Number of code words in TSPCW.

TSPCW - Table which contains a code word and the address of its z limits in A1ZL for each ray path that may exist between the target and sonobuoy on the present pass through the three layer ocean subroutines.

TABLE C2 (Cont.)

TTMP - Target time delay intermediate computation formed by FIN1 subroutine.

TTM1 - Calculated value of time delay for a value of z for a ray path.

UDGDT - Table which contains the possible propagation modes that can exist in the three layer ocean based only on the layer sound velocity gradients.

UDLCT - Number of modes in UDGDT.

ZMAX1 - Maximum z limit value for the ray path being calculated.

ZMNAD - Address of the z minimum limit for the ray path being calculated.

ZMXAD - Address of the z maximum limit for the ray path being calculated.

ZVAL1 - Value of z used in the calculation of the propagation parameters for a particular ray path.

ZVATA - Address of the z value used to start the Newton-Raphson calculation for a ray path.

PROPM SUBROUTINE

1. The PROPM subroutine calls the rest of the three layer ocean subroutines which calculate the ocean propagation parameters for a given target - sonobuoy pair based on their geometry at that particular moment of the ASGS problem.

2. ONLO3, which is part of the main ASGS executive program.

3.
```
        JSR@ .PROP
        .SnXH
        .TmXH
        m1NBS
        mnNLP
        mnNBM
    .
    .
    .
.PROP:  PROPM
```

4. NONE

5. NONE

6. NONE

7. See Figure C1,

8. See Listing C1.

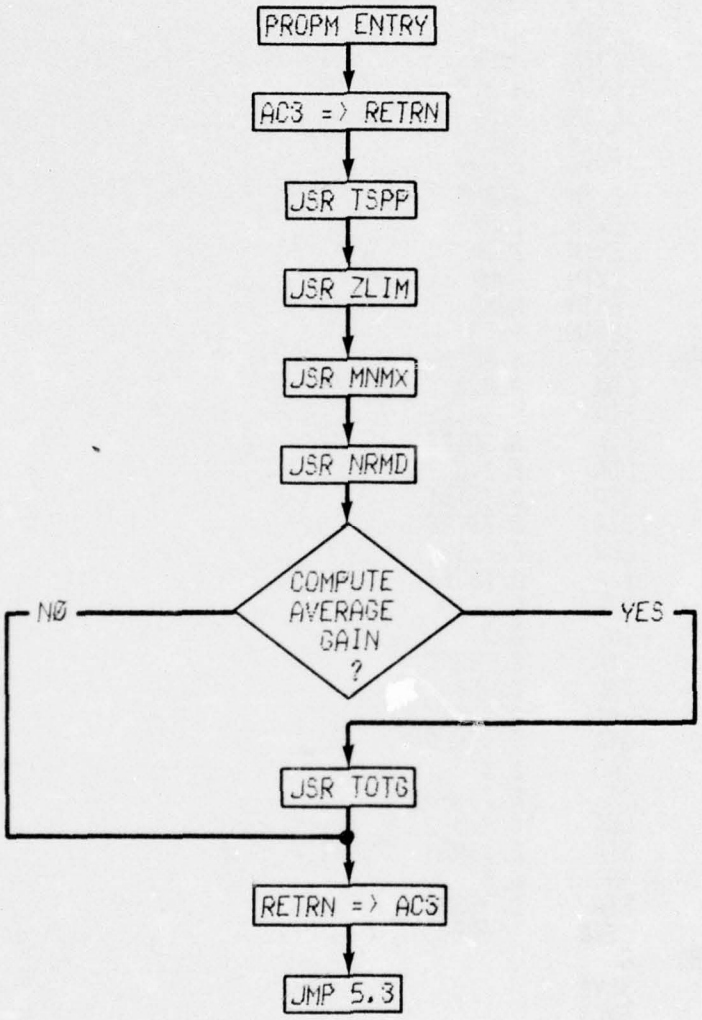

PROPM ENTRY
AC3 => RETRN
JSR TSPP
JSR ZLIM
JSR MNMX
JSR NRMD
COMPUTE AVERAGE GAIN ?
NØ
YES
JSR TOTG
RETRN => AC3
JMP 5.3

FIG. C1

```
---
0001  PROPM
                          .NREL
                          .TITL   PROPM   ;09/05/74
        000010            .RDX    8
                          .ENT    PROPM
                          .EXTN   SLY1
                          .EXTN   SLYA
                          .EXTN   SVL1
                          .EXTN   SVLA
                          .EXTN   A1PCT
                          .EXTN   A1PP
                          .EXTN   A1ZL
                          .EXTN   A1MM
                          .EXTN   A1HR
                          .EXTN   A1CW
                          .EXTN   A1NLP
                          .EXTN   A1BST
                          .EXTN   A1LPW
                          .EXTN   A1NBM
                          .EXTN   A1BMS
                          .EXTN   TSPP
                          .EXTN   ZLIM
                          .EXTN   MNMX
                          .EXTN   NRMD
                          .EXTN   TOTG
00000'054504 PROPM:       STA     3,RETRN
00001'021400              LDA     0,0,3
00002'040424              STA     0,SNTB1
00003'040444              STA     0,SNTB2
00004'021401              LDA     0,1,3
00005'040424              STA     0,TGTB1
00006'040442              STA     0,TGTB2
00007'021402              LDA     0,2,3
00010'040462              STA     0,TSNBS
00011'040467              STA     0,AD1
00012'101400              INC     0,0
00013'040460              STA     0,TSBST
00014'040465              STA     0,AD2
00015'021403              LDA     0,3,3
00016'040452              STA     0,TSNLP
00017'101400              INC     0,0
00020'040451              STA     0,TSLPW
00021'021404              LDA     0,4,3
00022'040452              STA     0,TSNBM
00023'101400              INC     0,0
00024'040451              STA     0,TSBMS
00025'006460              JSR@    .TSPP
00026'000000 SNTB1:       0
00027'177777              SLY1
00030'177777              SVL1
00031'000000 TGTB1:       0
00032'177777              SLYA
00033'177777              SVLA
00034'177777              A1PCT
00035'177777              A1PP
00036'006450              JSR@    .ZLIM
00037'000034'             A1PCT
00040'000035'             A1PP
00041'000033'             SVLA
00042'000030'             SVL1
```

```
0002  PROPM
  00043'177777          A1ZL
  00044'000027'         SLY1
  00045'000032'         SLYA
  00046'006441          JSR@    .MNMX
  00047'000000 SNTB2:   Ø
  00050'000000 TGTB2:   Ø
  00051'000037'         A1PCT
  00052'000040'         A1PP
  00053'000043'         A1ZL
  00054'177777          A1MM
  00055'177777          A1HR
  00056'177777          A1CW
  00057'006431          JSR@    .NRMD
  00060'000044'         SLY1
  00061'000045'         SLYA
  00062'000042'         SVL1
  00063'000041'         SVLA
  00064'000055'         A1HR
  00065'000051'         A1PCT
  00066'000056'         A1CW
  00067'000054'         A1MM
  00070'177777 TSNLP:   A1NLP
  00071'177777 TSLPW:   A1LPW
  00072'000000 TSNBS:   Ø
  00073'000000 TSBST:   Ø
  00074'177777 TSNBM:   A1NBM
  00075'177777 TSBMS:   A1BMS
  00076'000404          JMP     ARND1
  00077'006412          JSR     @.TOTG
  00100'000000 AD1:     Ø
  00101'000000 AD2:     Ø
  00102'034402 ARND1:   LDA     3,RETRN
  00103'001405          JMP     5,3
  00104'000000 RETRN:   Ø
  00105'177777 .TSPP:   TSPP
  00106'177777 .ZLIM:   ZLIM
  00107'177777 .MNMX:   MNMX
  00110'177777 .NRMD:   NRMD
  00111'177777 .TOTG:   TOTG
                        .END
```

LISTING C1 (Continued)

GRADS SUBROUTINE

1. The GRADS subroutine computes the sound velocity gradients for the three layer ocean and compiles a table of possible propagation modes.

2. Main ASGS executive at the start of the problem generation or when the contents of LYDPP or LYVEL are changed.

3.
```
          JSR@ . GRAD
            .
            .
            .
    .GRAD:  GRADS
```

4. Floating point math package (FPMP)

5. LYDPP and LYVEL

6. GDTBL, UDLCT, and UDGDT

7. See Figure C2.

8. See Listing C2.

9. The table of possible propagation modes is found in the following manner.

   a. All layers which have negative gradients plus the surface of the ocean are possible tops of modes.

   b. All layers which have positive gradients plus the bottom of the ocean are possible bottoms of modes.

c. All possible combinations of tops and bottoms are used to form the table of possible propagation modes, UDGDT, with the restriction that the number of the top of a mode must be less than the number of the bottom of the mode.

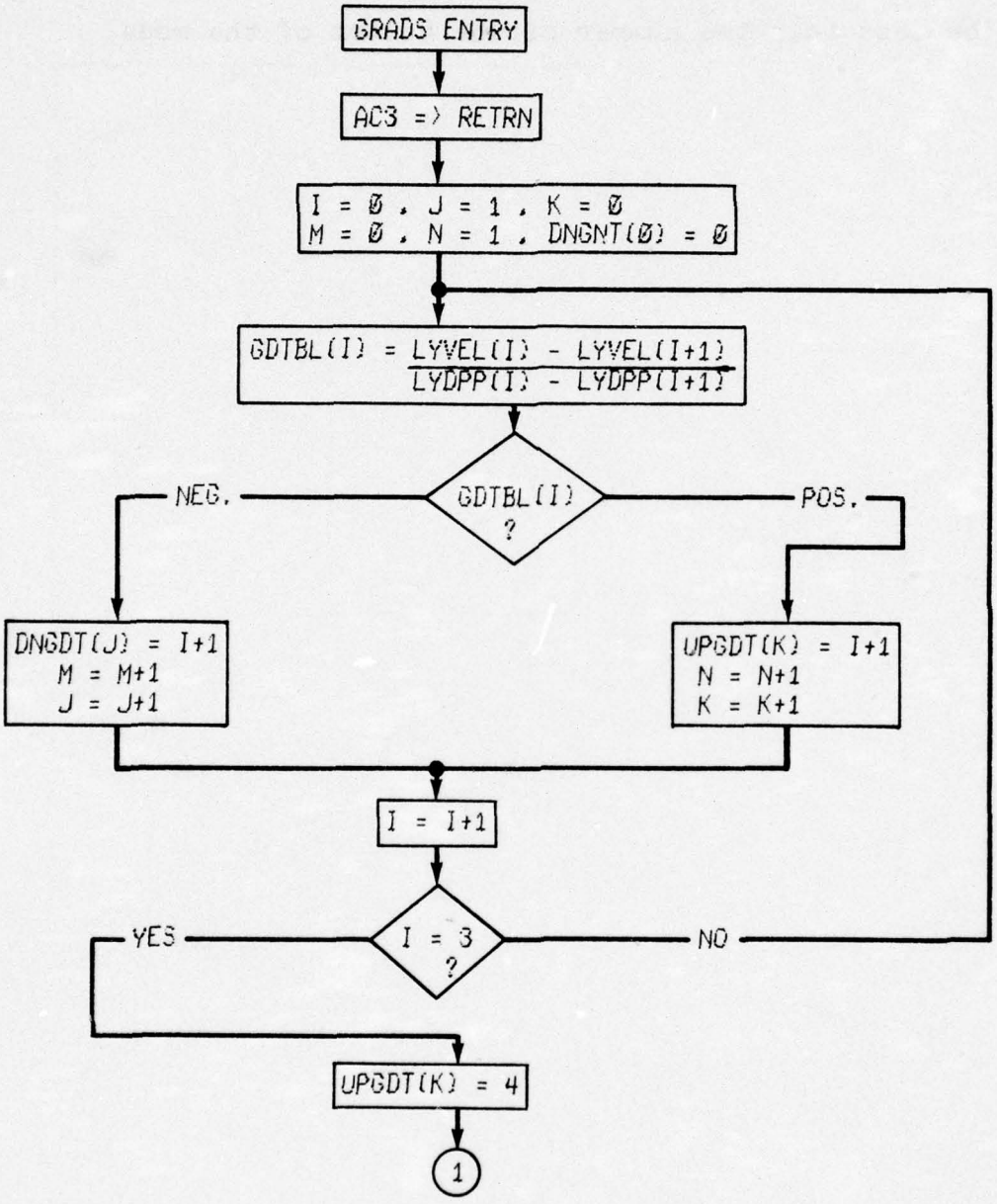

GRADS ENTRY
AC3 => RETRN
I = Ø , J = 1 , K = Ø
M = Ø , N = 1 , DNGNT(Ø) = Ø
GDTBL(I) = LYVEL(I) - LYVEL(I+1) / LYDPP(I) - LYDPP(I+1)
GDTBL(I) ?
NEG.
POS.
DNGDT(J) = I+1
M = M+1
J = J+1
UPGDT(K) = I+1
N = N+1
K = K+1
I = I+1
I = 3 ?
YES
NO
UPGDT(K) = 4
1

FIG. C2

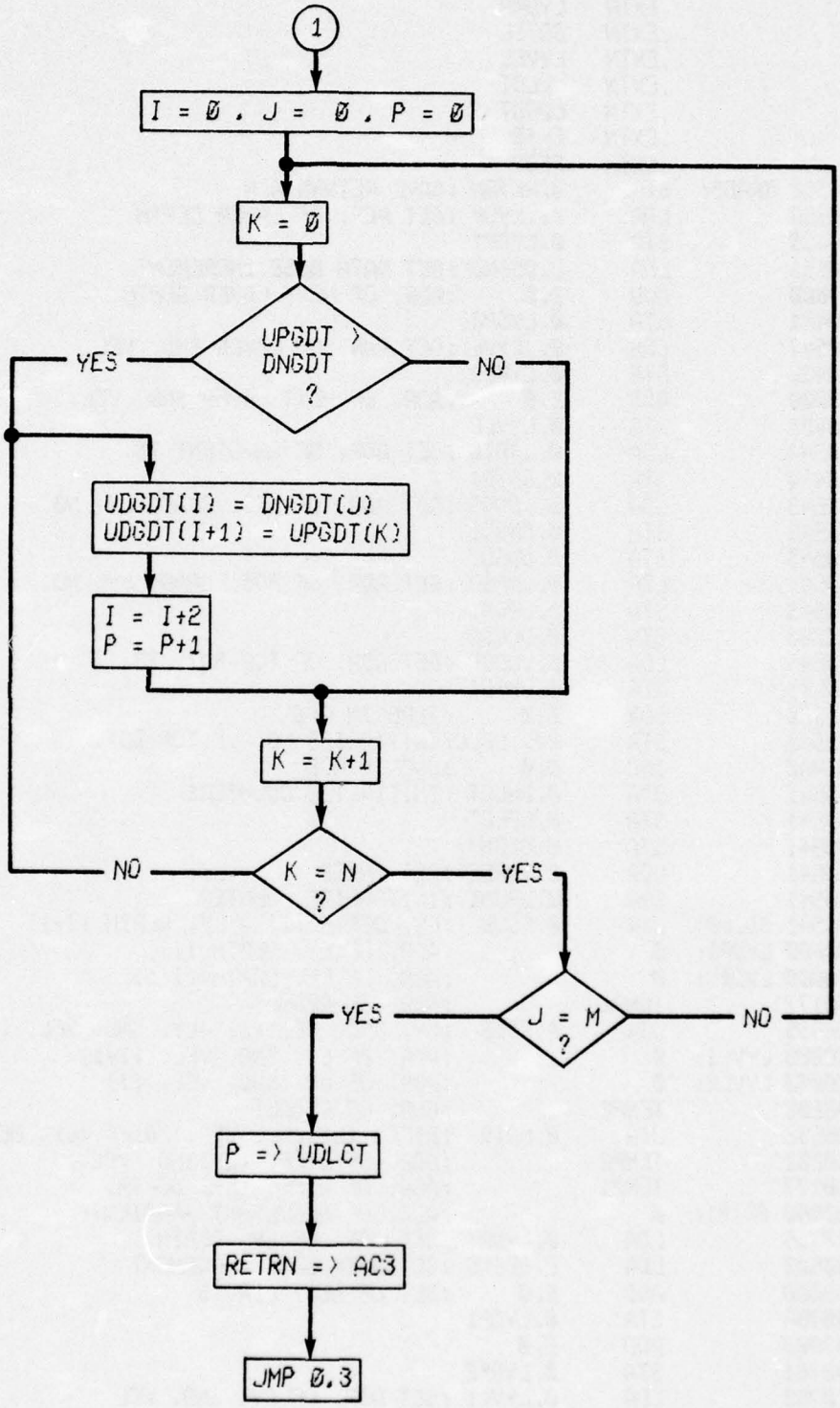


FIG. C2 (CONTINUED)

```
                        .NREL
                        .TITL   GRADS   ;12/03/73
        000010          .RDX    8
                        .ENT    GRADS
                        .EXTN   LYDPP
                        .EXTN   GDTBL
                        .EXTN   LYVEL
                        .EXTN   UDLCT
                        .EXTN   UDGDT
                        .EXTN   FFSB
                        .EXTN   FFDV
00000'054552 GRADS:     STA     3,RETRN ;SAVE RETURN ADR.
00001'020552            LDA     0,.LYDP ;GET ADR. OF LAYER DEPTH
00002'040436            STA     0,LYDP1
00003'030551            LDA     2,DBINC ;GET DATA BASE INCREMENT
00004'143000            ADD     2,0     ;ADR. OF NEXT LAYER DEPTH
00005'040431            STA     0,LYDP2
00006'020547            LDA     0,.LYVL ;GET ADR. OF LAYER SND. VEL.
00007'040432            STA     0,LYVL1
00010'143000            ADD     2,0     ;ADR. OF NEXT LAYER SND. VEL.
00011'040431            STA     0,LYVL2
00012'020544            LDA     0,.GDTB ;GET ADR. OF GRADIENT TB.
00013'040434            STA     0,GDTB1
00014'020543            LDA     0,.DNGD ;GET ADR. OF NEG. GRAD. LY. NO.
00015'040543            STA     0,DNGD1
00016'040543            STA     0,DNGD2
00017'020543            LDA     0,.UPGD ;GET ADR. OF POS. GRAD. LY. NO.
00020'040543            STA     0,UPGD1
00021'040543            STA     0,UPGD2
00022'020543            LDA     0,.UDGD ;GET ADR. OF TOP-BOT. TB.
00023'040543            STA     0,UDGD1
00024'102400            SUB     0,0     ;ZERO IN AC0
00025'042542            STA     @0,.UDLC;INITIALIZE NO. OF TOP-BOT.
00026'101400            INC     0,0     ;ONE IN AC0
00027'040541            STA     0,DNLCT ;INITIALIZE COUNTERS
00030'040541            STA     0,UPLCT
00031'040541            STA     0,GDCNT
00032'020541            LDA     0,THREE ;GET THREE
00033'040541            STA     0,LPCN1 ;INITIALIZE COUNTER
00034'006541 GDLOP:     JSR     @.FSUB  ;LY. DEPTH (I) - LY. DEPTH (I+1)
00035'000000 LYDP1:     0               ;ADR. OF LY. DEPTH (I)
00036'000000 LYDP2:     0               ;ADR. OF LY. DEPTH (I+1)
00037'000177'           TEMP1           ;ADR. OF RESULT
00040'006535            JSR     @.FSUB  ;LY. SND. VEL (I) -LY. SND. VEL. (I+1)
00041'000000 LYVL1:     0               ;ADR. OF LY. SND. VEL. (I+1)
00042'000000 LYVL2:     0               ;ADR. OF LY. SND. VEL. (I)
00043'000202'           TEMP2           ;ADR. OF RESULT
00044'006532            JSR     @.FDIV  ;DIFF. (LY.SND. VEL.)/DIFF (LY. DEPTH)
00045'000202'           TEMP2           ;ADR. OF DIFF. (LY.SND. VEL.)
00046'000177'           TEMP1           ;ADR. OF DIFF. (LY. DEPTH)
00047'000000 GDTB1:     0               ;ADR. OF RESULTANT GRADIENT
00050'020765            LDA     0,LYDP1 ;GET ADR. OF LY. DEPTH
00051'030503            LDA     2,DBINC ;GET DATA BASE INCREMENT
00052'143000            ADD     2,0     ;SET UP NEXT ADR.'S
00053'040762            STA     0,LYDP1
00054'143000            ADD     2,0
00055'040761            STA     0,LYDP2
00056'020763            LDA     0,LYVL1 ;GET ADR. OF LY. SND. VEL
00057'143000            ADD     2,0     ;SET UP NEXT ADR.'S
```

LISTING C2

```
 00060'040761          STA     0.LYVL1
 00061'143000          ADD     2.0
 00062'040760          STA     0.LYVL2
 00063'034764          LDA     3.GDTB1 ;GET ADR. OF GRADIENT TB.
 00064'021401          LDA     0.1.3   ;GET GRADIENT
 00065'157000          ADD     2.3     ;SET UP NEXT ADR.
 00066'054761          STA     3.GDTB1
 00067'024503          LDA     1.GDCNT ;GET LAYER NO. BEING CHECKED
 00070'101103          MOVL    0.0.SNC ;SKIP IF GRADIENT IS NEG.
 00071'000407          JMP     ENTR1   ;GO TO POSITIVE GRAD. STORAGE
 00072'030466          LDA     2.DNGD1 ;GET ADR.OF NEG. GRAD. LY. NO.
 00073'045001          STA     1.1.2   ;STORE LY. NO. IN TB.
 00074'151400          INC     2.2     ;SET UP NEXT ADR.
 00075'050463          STA     2.DNGD1
 00076'010472          ISZ     DNLCT   ;INCREMENT NO. OF NEG. GRAD.
 00077'000406          JMP     ENTR2   ;JUMP AROUND POS. GRAD STORAGE
 00100'030463 ENTR1:   LDA     2.UPGD1 ;GET ADR. OF POS. GRAD. LY. NO.
 00101'045000          STA     1.0.2   ;STORE LY. NO. IN TB.
 00102'151400          INC     2.2     ;SET UP NEXT ADR.
 00103'050460          STA     2.UPGD1
 00104'010465          ISZ     UPLCT   ;INCREMENT NO. OF POS.GRAD.
 00105'010465 ENTR2:   ISZ     GDCNT   ;INCREMENT LY. NO. BEING CK.
 00106'014466          DSZ     LPCN1   ;SKIP AFTER ALL LY.'S ARE CK.
 00107'000725          JMP     GDLOP   ;COMPUTE NEXT GRADIENT
 00110'020475          LDA     0.FOUR  ;GET FOUR
 00111'041000          STA     0.0.2   ;INSERT BOT. LAYER NO.
 00112'020456          LDA     0.DNLCT ;GET NO. OF TOPS
 00113'040473          STA     0.CNTR1
 00114'034445          LDA     3.DNGD2 ;GET ADR. OF TOP LY. NO. TB.
 00115'020454 LOOP1:   LDA     0.UPLCT ;GET NO. OF BOTTOMS
 00116'040471          STA     0.CNTR2
 00117'025400          LDA     1.0.3   ;GET TOP LY. NO.
 00120'034442          LDA     3.,UPGD ;GET ADR. OF BOT. LY. NO. TB.
 00121'054443          STA     3.UPGD2
 00122'034442 LOOP2:   LDA     3.UPGD2 ;GET ADR. OF BOT. LY. NO. TB.
 00123'021400          LDA     0.0.3   ;GET BOT. LY. NO.
 00124'175400          INC     3.3     ;SET UP NEXT ADR.
 00125'054437          STA     3.UPGD2
 00126'030440          LDA     2.UDGD1 ;GET ADR. OF TOP-BOT. TB.
 00127'106513          SUBL#   0.1.SNC ;SKIP IF BOT. NO >TOP NO.
 00130'000407          JMP     ENTR3   ;SOLUTION NOT VALID
 00131'041001          STA     0.1.2   ;STORE BOT LY. NO. IN TB.
 00132'045000          STA     1.0.2   ;STORE TOP LY. NO. IN TB.
 00133'151400          INC     2.2     ;SET UP NEXT ADR.
 00134'151400          INC     2.2
 00135'050431          STA     2.UDGD1
 00136'012431          ISZ     @.UDLC  ;INCREMENT NO. OF SOLUTIONS
 00137'014450 ENTR3:   DSZ     CNTR2   ;SKIP AFTER ALL BOT. NO. CK.
 00140'000762          JMP     LOOP2   ;GET NEXT BOT. NO.
 00141'014445          DSZ     CNTR1   ;SKIP AFTER ALL TOP NO. CK.
 00142'000402          JMP     ENTR4   ;CONTINUE
 00143'000405          JMP     ENTR5   ;JUMP TO END
 00144'034415 ENTR4:   LDA     3.DNGD2 ;GET ADR. OF TOP LY. NO. TB.
 00145'175400          INC     3.3     ;SET UP NEXT ADR.
 00146'054413          STA     3.DNGD2
 00147'000746          JMP     LOOP1   ;GET NEXT TOP NO.
 00150'034402 ENTR5:   LDA     3.RETRN ;GET RETURN ADR.
 00151'001400          JMP     0.3     ;RETURN
 00152'000000 RETRN:   0
```

LISTING C2 (Continued)

```
0003  GRADS
 00153'177777 .LYDP:   LYDPP
 00154'000003 DBINC:   3
 00155'177777 .LYVL:   LYVEL
 00156'177777 .GDTB:   GDTBL
 00157'000210'.DNGD:   DNGDT
 00160'000000 DNGD1:   0
 00161'000000 DNGD2:   0
 00162'000214'.UPGD:   UPGDT
 00163'000000 UPGD1:   0
 00164'000000 UPGD2:   0
 00165'177777 .UDGD:   UDGDT
 00166'000000 UDGD1:   0
 00167'177777 .UDLC:   UDLCT
 00170'000000 DNLCT:   0
 00171'000000 UPLCT:   0
 00172'000000 GDCNT:   0
 00173'000003 THREE:   3
 00174'000000 LPCN1:   0
 00175'177777 .FSUB:   FFSB
 00176'177777 .FDIV:   FFDV
 00177'000000 TEMP1:   0
 00200'000000          0
 00201'000000          0
 00202'000000 TEMP2:   0
 00203'000000          0
 00204'000000          0
 00205'000004 FOUR:    4
 00206'000000 CNTR1:   0
 00207'000000 CNTR2:   0
 00210'000000 DNGDT:   0
 00211'000000          0
 00212'000000          0
 00213'000000          0
 00214'000000 UPGDT:   0
 00215'000000          0
 00216'000000          0
 00217'000000          0
                       .END
```

LISTING C2 (Continued)

TSPP SUBROUTINE

1. The TSPP subroutine finds the layers in which the target and sonobuoy are located and computes the sound velocities at their locations. This subroutine also eliminates some of the modes from the table of possible propagation modes found in the GRADS subroutine.

2. PROPM

3.
```
        JSR@ .TSPP
        .SnXH
        SLY1
        SVL1
        .TmXH
        SLYA
        SVLA
        A1PCT
        A1PP
    .
    .
    .
.TSPP:  TSPP
```

4. FPMP

5. .SnXH, .TmXH, LYVEL, LYDPP, GDTBL, UDLCT, and UDGDT

6. SLY1, SVL1, SLYA, SVLA, A1PCT, and A1PP

7. See Figure C3 .

8. See Listing C3.

9. The criteria for eliminating some of the possible propagation modes contained in UDGDT is that for a mode to exist it must encompass both of the layers occupied by the target and sonobuoy.

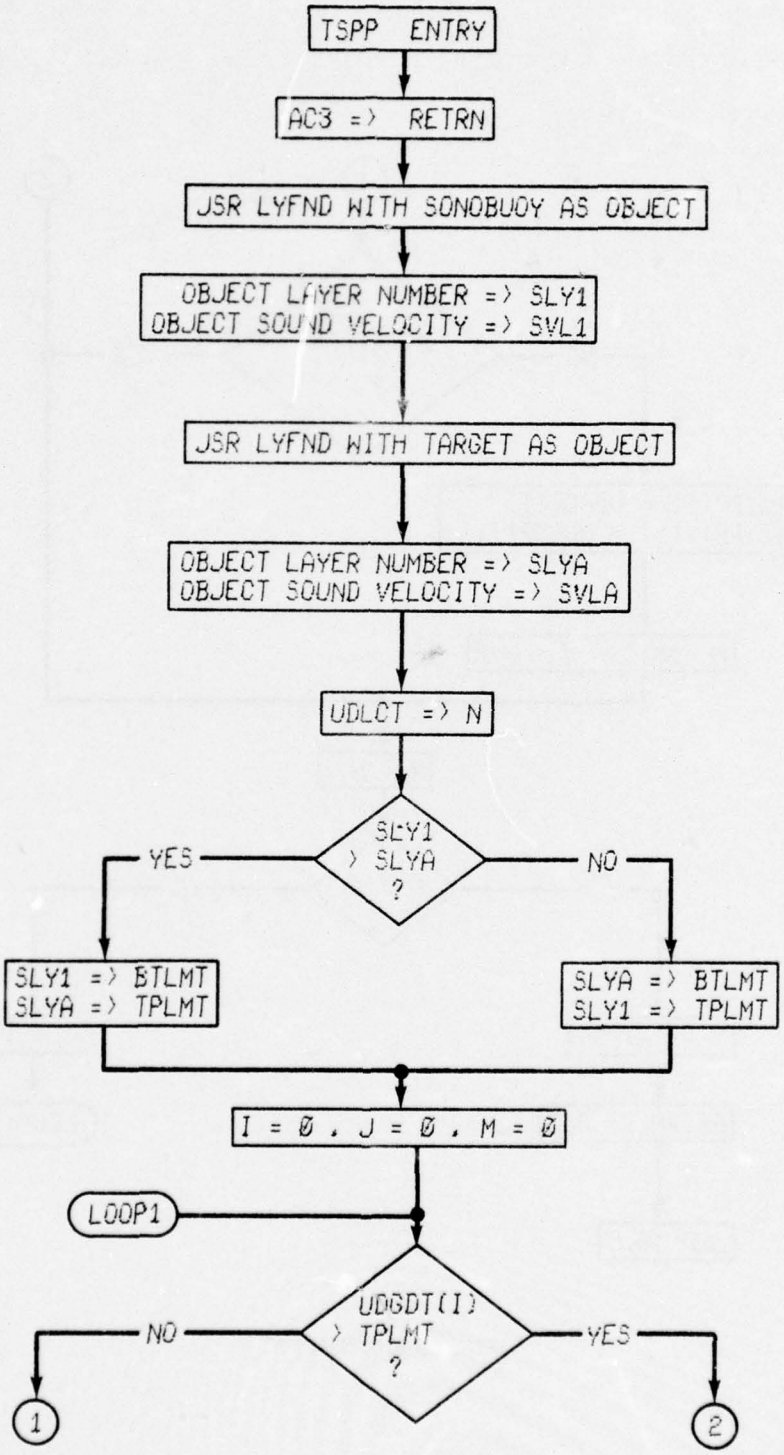

TSPP ENTRY
AC3 => RETRN
JSR LYFND WITH SONOBUOY AS OBJECT
OBJECT LAYER NUMBER => SLY1
OBJECT SOUND VELOCITY => SVL1
JSR LYFND WITH TARGET AS OBJECT
OBJECT LAYER NUMBER => SLYA
OBJECT SOUND VELOCITY => SVLA
UDLCT => N
SLY1 > SLYA ?
YES
NO
SLY1 => BTLMT
SLYA => TPLMT
SLYA => BTLMT
SLY1 => TPLMT
I = Ø , J = Ø , M = Ø
LOOP1
UDGDT(I) > TPLMT ?
NO
YES
1
2

FIG. C3

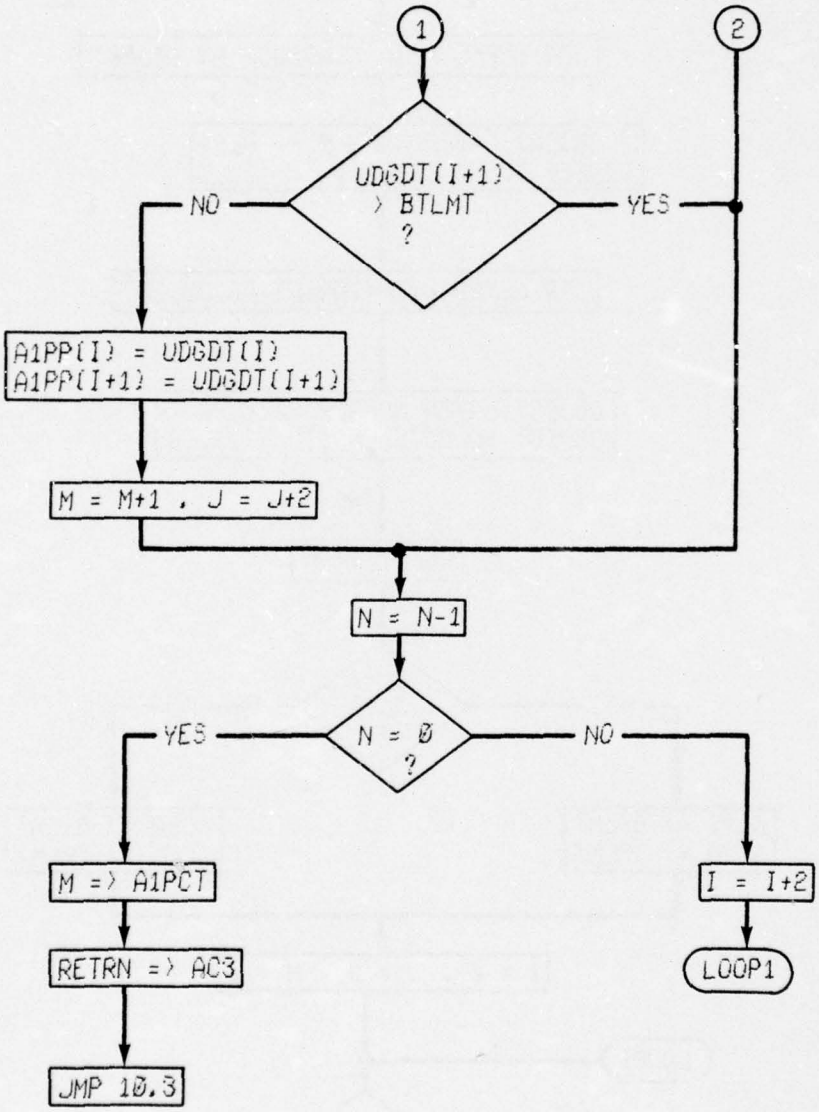


FIG. C3 (CONTINUED)

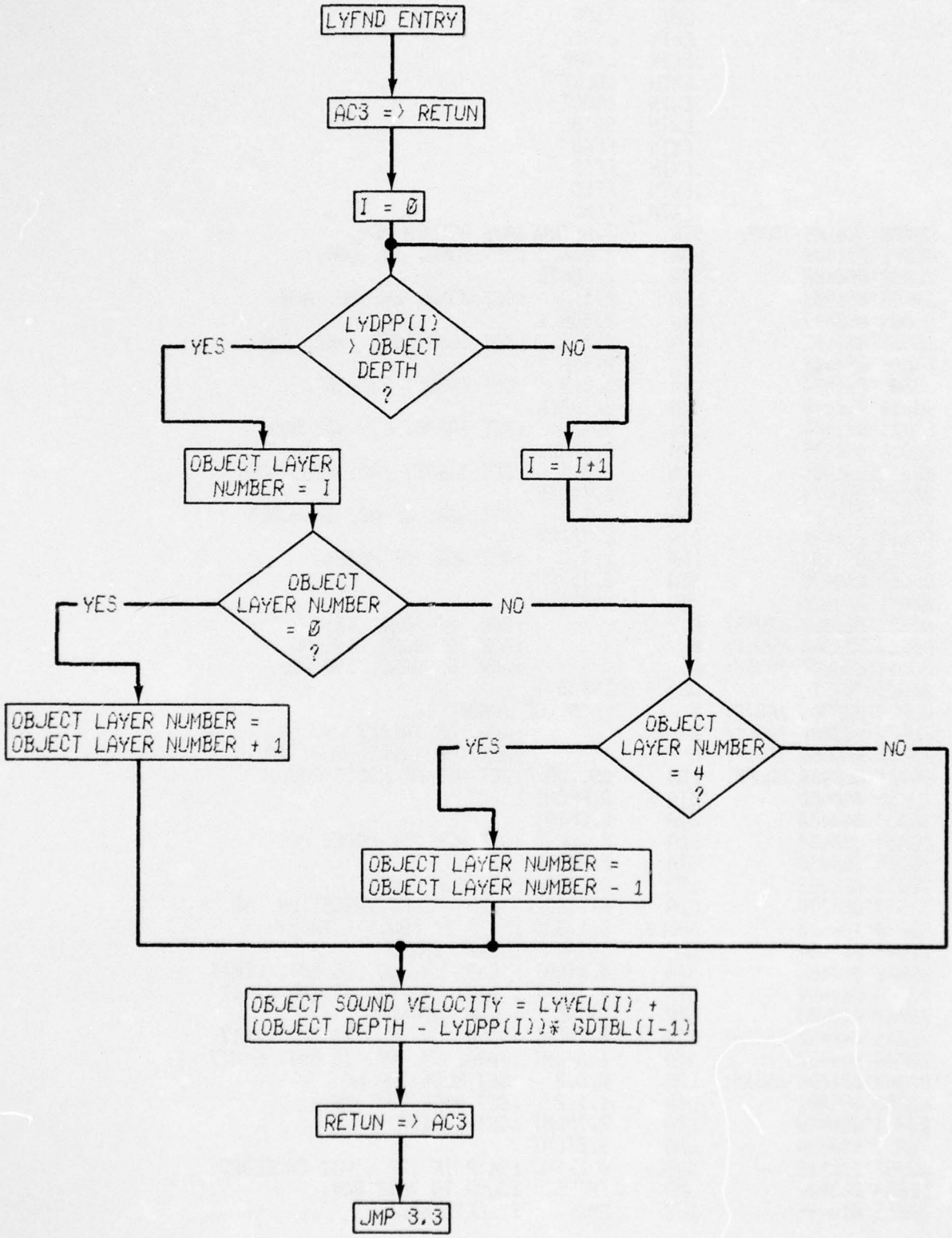


FIG. C3 (CONTINUED)

```
                    .NREL
                    .TITL   TSPP    ;03/01/74
        000010      .RDX    8
                    .ENT    TSPP
                    .EXTN   LYVEL
                    .EXTN   LYDPP
                    .EXTN   UDLCT
                    .EXTN   UDGDT
                    .EXTN   GDTBL
                    .EXTN   FFAD
                    .EXTN   FFSB
                    .EXTN   FFLD
                    .EXTN   FFML
00000'054505 TSPP:  STA     3,RETRN;SAVE RETURN ADR.
00001'031400        LDA     2,0,3   ;GET SONO. TB. ADR.
00002'050420        STA     2,SONTB
00003'031401        LDA     2,1,3   ;GET SONO. LY. NO. ADR.
00004'050417        STA     2,SONL1
00005'031402        LDA     2,2,3   ;GET SONO. SND. VEL. ADR.
00006'050416        STA     2,SONSV
00007'031403        LDA     2,3,3   ;GET TARGET TB. ADR.
00010'050416        STA     2,TAGTB
00011'031404        LDA     2,4,3   ;GET TARGET LY. NO. ADR.
00012'050415        STA     2,TAGL1
00013'031405        LDA     2,5,3   ;GET TARGET SND. VEL. ADR.
00014'050414        STA     2,TAGSV
00015'031406        LDA     2,6,3   ;GET ADR. OF NO. OF MODES
00016'050471        STA     2,TSPCT
00017'031407        LDA     2,7,3   ;GET ADR. OF MODES
00020'050470        STA     2,TSPPH
00021'004520        JSR     LYFND
00022'000000 SONTB: 0               ;ADR. OF SONO. TB.
00023'000000 SONL1: 0               ;ADR. OF SONO. LY. NO.
00024'000000 SONSV: 0               ;ADR. OF SONO. SND VEL.
00025'004514        JSR     LYFND
00026'000000 TAGTB: 0       ;ADR. OF TARGET TB.
00027'000000 TAGL1: 0               ;ADR. OF TARGET LY. NO.
00030'000000 TAGSV: 0               ;ADR. OF TARGET SND. VEL.
00031'022460 ADJPP: LDA     @0,.UDLC;GET NO. OF MODES POSS.
00032'040460        STA     0,PPCNT
00033'040460        STA     0,CNTR1
00034'030460        LDA     2,.UDGD ;GET ADR. OF MODES POSS.
00035'050460        STA     2,PPHTA
00036'022765        LDA     @0,SONL1;GET SONO. LY. NO.
00037'026770        LDA     @1,TAGL1        ;GET TARGET LY. NO.
00040'106513        SUBL#   0,1,SNC ;SKIP IF SONLY > TAGLY
00041'000404        JMP     ENTR4   ;JUMP AROUND
00042'040454        STA     0,BTLMT ;SONO. LY. NO. IS BOT. LIMIT
00043'044454        STA     1,TPLMT ;TARG. LY. NO. IS TOP LIMIT
00044'000403        JMP     ENTR5   ;JUMP AROUND
00045'040452 ENTR4: STA     0,TPLMT ;SONO. LY. NO. IS TOP LIMIT
00046'044450        STA     1,BTLMT ;TARG. LY. NO. IS BOT. LIMIT
00047'021000 ENTR5: LDA     0,0,2   ;GET MODE TOP NO.
00050'025001        LDA     1,1,2   ;GET MODE BOT. NO.
00051'030446        LDA     2,TPLMT ;GET LIMITS
00052'034444        LDA     3,BTLMT
00053'112513        SUBL#   0,2,SNC ;SKIP IF TOP LIMIT EXCEEDED
00054'000404        JMP     ENTR6   ;JUMP TO TEST BOT.
00055'014435        DSZ     PPCNT   ;DELETE MODE
```

```
00056'101000          MOV     0,0
00057'000414          JMP     ENTR8   ;JUMP AROUND
00060'166513 ENTR6:   SUBL#   3,1,SNC ;SKIP IF BOT. LIMIT EXCEEDED
00061'000404          JMP     ENTR7   ;JUMP TO STORE SOLUTION
00062'014430          DSZ     PPCNT   ;DELETE MODE
00063'101000          MOV     0,0
00064'000407          JMP     ENTR8   ;JUMP AROUND
00065'030423 ENTR7:   LDA     2,TSPPH ;GET ADR. OF MODES
00066'041000          STA     0,0,2   ;STORE TOP NO.
00067'045001          STA     1,1,2   ;STORE BOT. NO.
00070'151400          INC     2,2     ;SET UP NEXT ADR.
00071'151400          INC     2,2
00072'050416          STA     2,TSPPH
00073'030422 ENTR8:   LDA     2,PPHTA ;GET ADR. OF MODES POSS.
00074'151400          INC     2,2     ;SET UP NEXT ADR.
00075'151400          INC     2,2
00076'050417          STA     2,PPHTA
00077'014414          DSZ     CNTR1   ;SKIP IF ALL MODES CHECKED
00100'000747          JMP     ENTR5   ;TEST NEXT POSS. MODE
00101'020411          LDA     0,PPCNT ;GET NO. OF MODES
00102'042405          STA     00,TSPCT;STORE NO. IN DATA BASE
00103'034402          LDA     3,RETRN ;GET RETURN ADR.
00104'001410          JMP     10,3    ;RETURN
00105'000000 RETRN:   0
00106'177777 .LYVL:   LYVEL
00107'000000 TSPCT:   0
00110'000000 TSPPH:   0
00111'177777 .UDLC:   UDLCT
00112'000000 PPCNT:   0
00113'000000 CNTR1:   0
00114'177777 .UDGD:   UDGDT
00115'000000 PPHTA:   0
00116'000000 BTLMT:   0
00117'000000 TPLMT:   0
00120'000000 RETUN:   0
00121'177777 .LYDP:   LYDPP
00122'000004 INCR1:   4
00123'000000 TEMA1:   0
00124'000000 TEMA2:   0
00125'000000 TEMA3:   0
00126'000000 TEMB1:   0
00127'000000          0
00130'000000          0
00131'177777 .FFLD:   FFLD
00132'177777 .FSUB:   FFSB
00133'000004 FOUR:    4
00134'000003 THREE:   3
00135'177777 .GDTB:   GDTBL
00136'000003 DBINC:   3
00137'177777 .FMUL:   FFML
00140'177777 .FADD:   FFAD
00141'054757 LYFND:   STA     3,RETUN ;SAVE RETURN ADR.
00142'030757          LDA     2,.LYDP ;GET ADR. OF LAYER DEPTHS
00143'050415          STA     2,LYDP1
00144'102400          SUB     0,0     ;ZERO IN AC0
00145'040746          STA     0,CNTR1 ;INITIALIZE COUNTER
00146'021400          LDA     0,0,3   ;GET ADR. OF OBJECT TB.
00147'024753          LDA     1,INCR1 ;GET DATA BASE INCREMENT
00150'107000          ADD     0,1     ;SET UP ADR. OF OBJ. DEPTH
```

LISTING C3 (Continued)

```
 00151'044402          STA     1.TEMCA
 00152'006757          JSR     @.FFLD  ;FLOAT OBJECT DEPTH
 00153'000000 TEMCA:   0               ;ADR. OF OBJECT DEPTH
 00154'000004          4               ;B4 DP
 00155'000126'         TEMB1           ;ADR. OF FL. PT. OBJ. DEPTH
 00156'006754 LOOP1:   JSR     @.FSUB  ;OBJ. DEPTH - LAYER DEPTH
 00157'000126'         TEMB1           ;ADR. OF OBJECT DEPTH
 00160'000000 LYDP1:   0               ;ADR. OF LAYER DEPTH
 00161'000123'         TEMA1           ;ADR. OF RESULT
 00162'020742          LDA     0.TEMA2 ;GET RESULT
 00163'101004          MOV     0.0.SZR ;SKIP IF RESULT ZERO
 00164'000402          JMP     ENTR1   ;TEST SIGN OF RESULT
 00165'000412          JMP     ENTR2   ;ZERO FIX
 00166'101112 ENTR1:   MOVL#   0.0.SZC ;SKIP IF OBJ. DPH>LY. DPH
 00167'000411          JMP     ENTR3   ;OBJ. IN THIS LAYER NO.
 00170'010723          ISZ     CNTR1   ;INCREMENT LAYER NO.
 00171'030767          LDA     2.LYDP1 ;GET ADR. OF LAYER DEPTH
 00172'151400          INC     2.2     ;SET UP NEXT ADR.
 00173'151400          INC     2.2
 00174'151400          INC     2.2
 00175'050763          STA     2.LYDP1
 00176'000760          JMP     LOOP1   ;TEST NEXT LAYER
 00177'010714 ENTR2:   ISZ     CNTR1   ;INCREMENT LAYER NO.
 00200'024713 ENTR3:   LDA     1.CNTR1 ;GET LAYER NO.
 00201'034732          LDA     3.FOUR  ;GET FOUR
 00202'136405          SUB     1.3.SNR ;SKIP IF LY. NO. <FOUR
 00203'024731          LDA     1.THREE ;USE THREE
 00204'034714          LDA     3.RETUN ;GET RETURN ADR.
 00205'031401          LDA     2.1.3   ;GET ADR. OF OBJ. LY. NO.
 00206'045000          STA     1.0.2   ;STORE NO. IN DATA BASE
 00207'044704          STA     1.CNTR1 ;SAVE OBJ. LY. NO.
 00210'020676          LDA     0.,LYVL ;GET ADR.OF LY. SND. VEL. TB.
 00211'030725          LDA     2.DBINC ;GET DATA BASE INCREMENT
 00212'073301          MUL             ;ADR. OF LY. SND. VEL. BELOW OBJ.
 00213'044420          STA     1.LYVL1
 00214'020721          LDA     0.,GDTB ;GET ADR. OF GRADIENT TB.
 00215'024676          LDA     1.CNTR1 ;GET OBJ. LY. NO.
 00216'176520          SUBZL   3.3     ;ONE IN AC3
 00217'166400          SUB     3.1     ;OBJ. LY.NO. - ONE
 00220'073301          MUL             ;ADR. OF OBJ. LY. GRADIENT
 00221'044402          STA     1.GDTB1
 00222'006715          JSR     @.FMUL  ;GRAD. TIMES DELTA DEPTH
 00223'000000 GDTB1:   0               ;ADR. OF GRADIENT
 00224'000123'         TEMA1           ;ADR. OF DELTA DEPTH
 00225'000126'         TEMB1           ;ADR. OF RESULT
 00226'034672          LDA     3.RETUN ;GET RETURN ADR.
 00227'021402          LDA     0.2.3   ;GET ADR. OF OBJ. SND. VEL.
 00230'040404          STA     0.TEMCB
 00231'006707          JSR     @.FADD  ;RESULT + LY. SND. VEL.
 00232'000126'         TEMB1           ;ADR. OF ABOVE RESULT
 00233'000000 LYVL1:   0               ;ADR. OF LY. SND. VEL. BELOW OBJ.
 00234'000000 TEMCB:   0               ;ADR. OF OBJ. SND. VEL.
 00235'034663          LDA     3.RETUN ;GET RETURN ADR.
 00236'001403          JMP     3.3
                       .END
```

LISTING C3 (Continued)

ZLIM SUBROUTINE

1. The ZLIM subroutine computes the maximum and minimum limit values that z can have for each possible propagation mode in A1PP. This subroutine also eliminations modes from A1PP based on these z limit values.

2. PROPM

3.
```
          JSR@ .ZLIM
          A1PCT
          A1PP
          SVLA
          SVL1
          A1ZL
          SLY1
          SLYA
     .
     .
     .
.ZLIM:    ZLIM
```

4. FPMP

5. LYVEL, A1PCT, A1PP, SVLA, SVL1, SLY1, AND SLYA

6. A1PCT, A1PP, and A1ZL

7. See Figure C4.

8. See Listing C4.

9. The z limits for each propagation mode in AlPP are found in the following manner.

a. First consider the layer or surface in which the ray paths turn downward (the top of the mode).

1. z maximum = sound velocity at the top of the layer.
2. z minimum = sound velocity at the bottom of the layer.
3. If the top of the mode is a 0, then replace z maximum with a conveniently large value. z minimum should then be set to the sound velocity at the top of the three layer ocean.

b. Next, consider the layer or surface in which the ray paths turn upward (the bottom of the mode).

1. z maximum = sound velocity at the bottom of the layer.
2. z minimum = sound velocity at the top of the layer.
3. If the bottom of the mode is a 4, then replace z maximum with the same large value mentioned in (a) 3. z minimum should then be set to the sound velocity at the bottom of the three layer ocean.

c. Next consider the location of the target and sonobuoy.

1. If the top of the mode contains the target replace the value of z minimum for the top with the sound velocity at the target.
2. If the top of the mode contains the sonobuoy replace the value of z minimum for the top with the sound velocity at the sonobuoy.

3. If both the target and sonobuoy are in the top of the mode replace the value of z minimum of the top with the larger of the two sound velocities.
4. If the top of the mode does not contain either a target or sonobuoy the values of the z limits for the top are correct.
5. Repeat steps c.) 1. through c.) 4. for the values of z limits for the bottom of the mode.

d. Next compare the values of the z limits from the top and bottom of the mode.
   1. Choose the larger value of the two z minimums as the z minimum of the propagation mode.
   2. Choose the smaller value of the two z maximums as the z maximum of the propagation mode.

e. Next compare the value of z minimum with all the sound velocities at the layer interfaces between the top and bottom of the mode. If any of these sound velocities are greater than z minimum replace z minimum with its value.

f. Finally if the value found for z maximum is not greater than the value found for z minimum, the propagation mode is eliminated from AlPP and the value of AlPCT decremented by one.

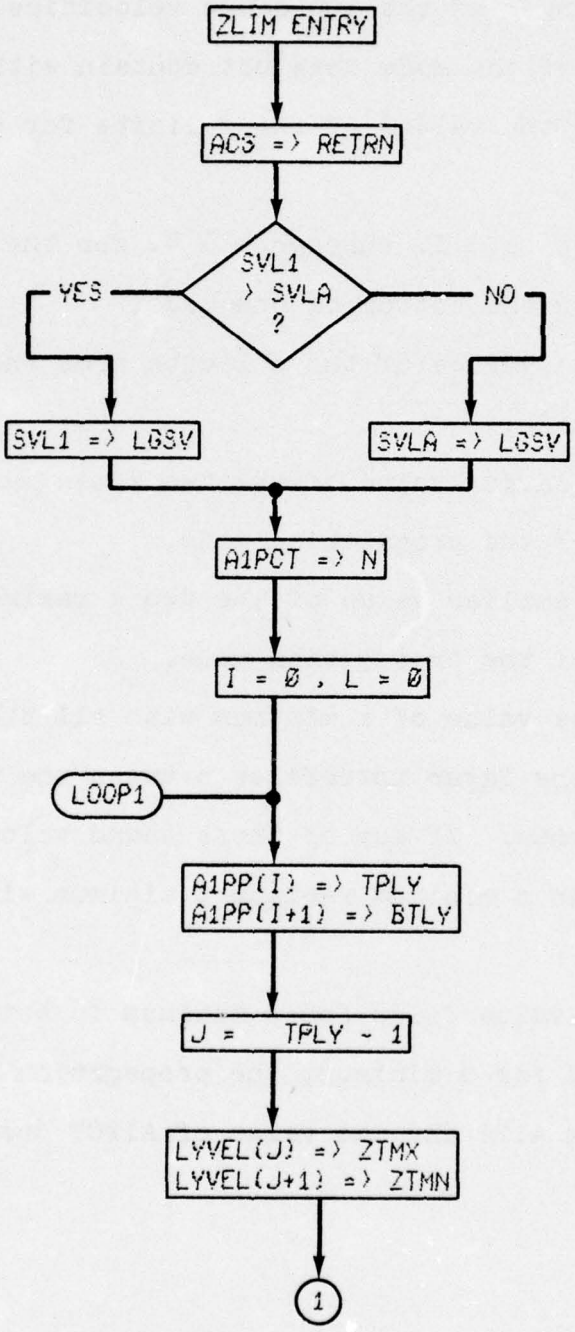

ZLIM ENTRY
ACS => RETRN
SVL1 > SVLA ?
YES
NO
SVL1 => LGSV
SVLA => LGSV
A1PCT => N
I = Ø , L = Ø
LOOP1
A1PP(I) => TPLY
A1PP(I+1) => BTLY
J = TPLY - 1
LYVEL(J) => ZTMX
LYVEL(J+1) => ZTMN
1

FIG. C4

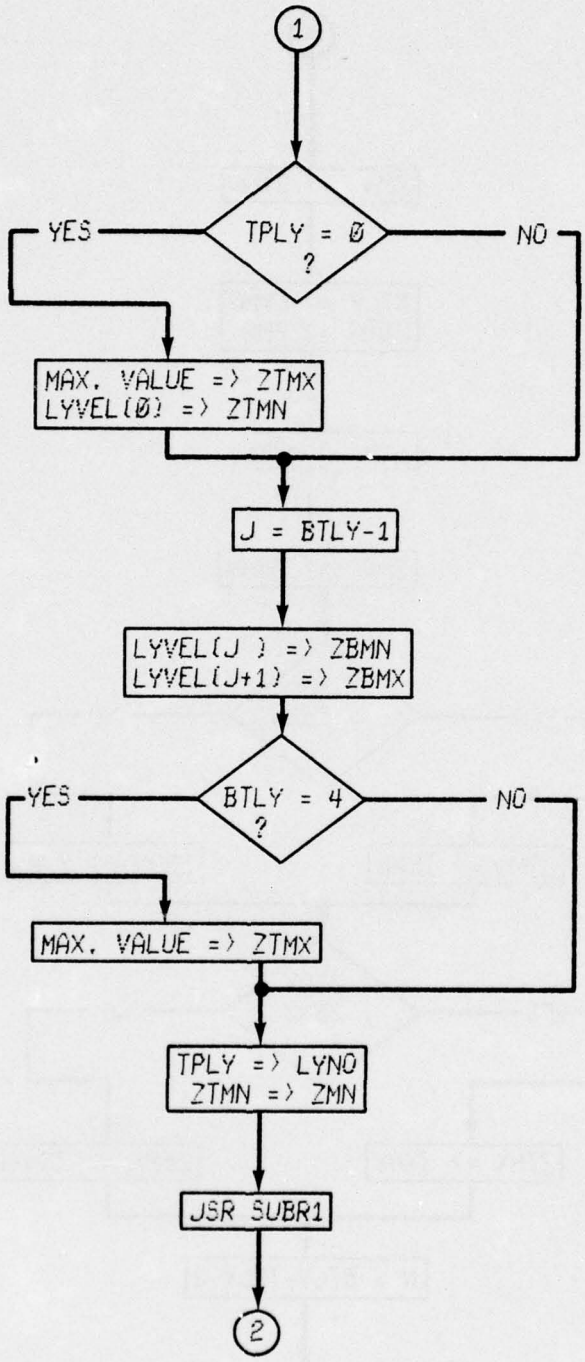


FIG. C4 (CONTINUED)

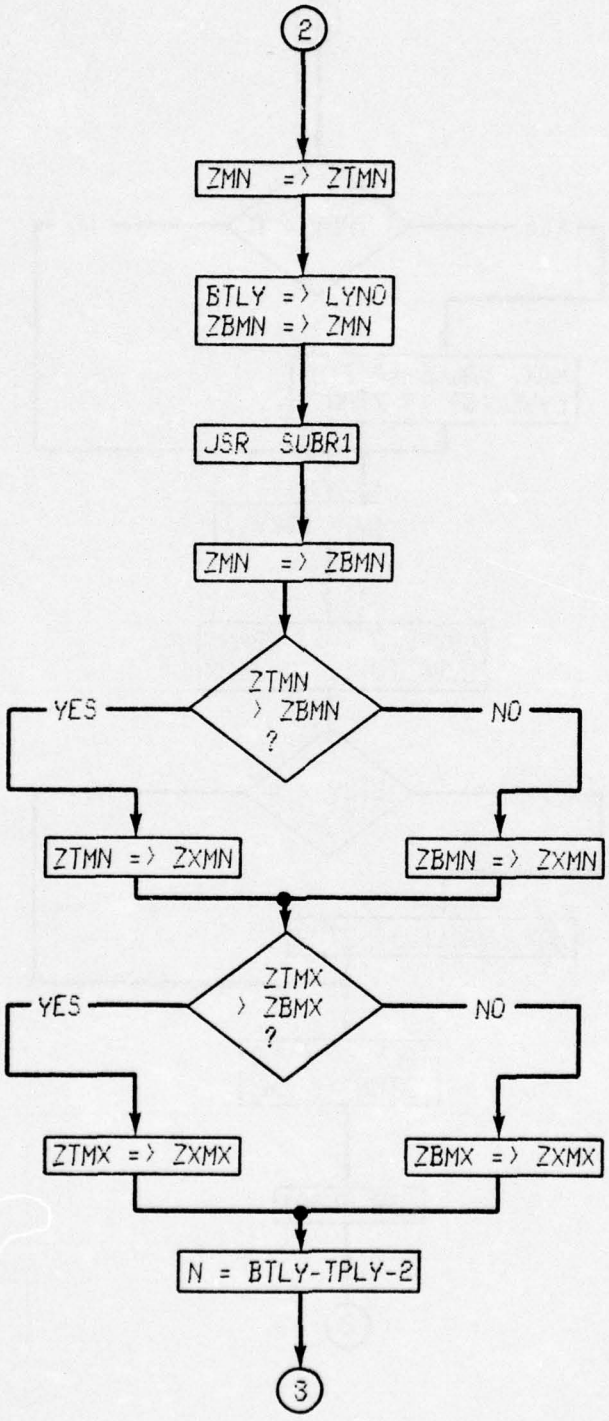


FIG. C4 (CONTINUED)

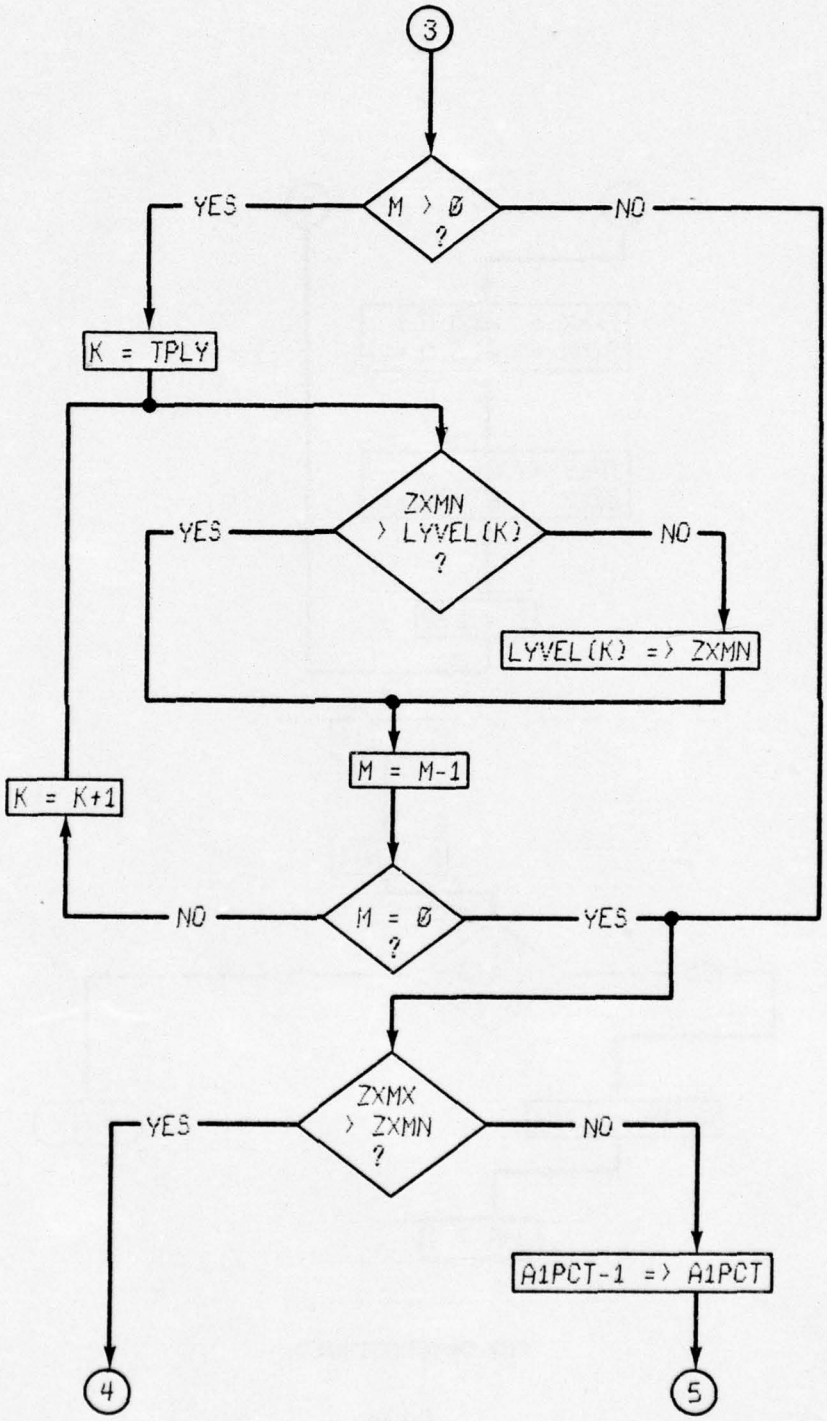


FIG. C4 (CONTINUED)

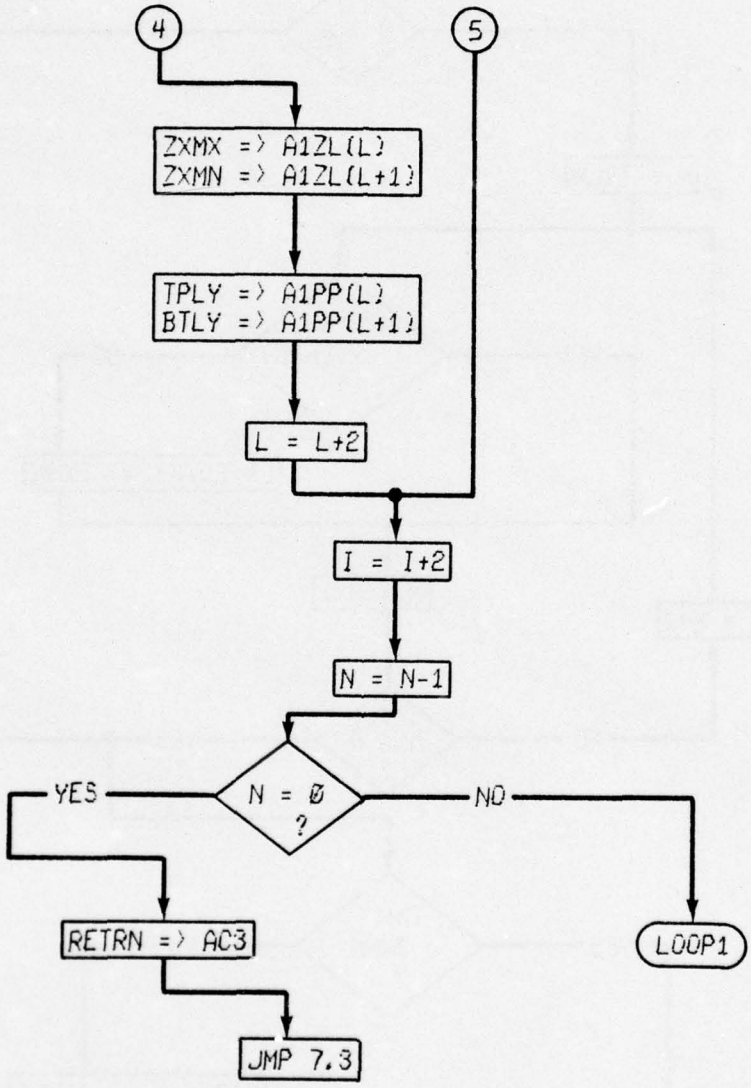


FIG. C4 (CONTINUED)

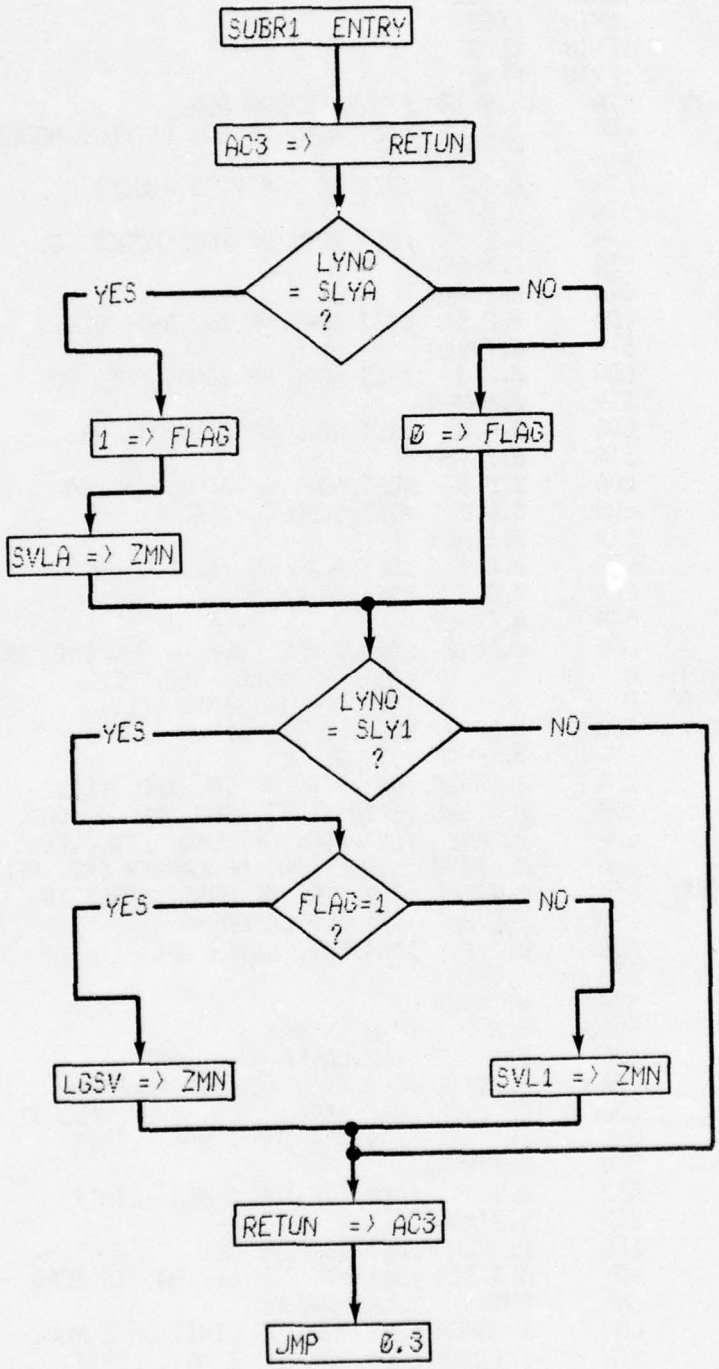


FIG. C4 (CONTINUED)

```
                        .NREL
                        .TITL   ZLIM    ;03/19/74
        000010          .RDX    8
                        .ENT    ZLIM
                        .EXTN   LYVEL
                        .EXTN   FFSB
                        .EXTN   FFAD
                        .EXTN   FFML
00000'054555 ZLIM:      STA     3,RETRN ;SAVE RETURN ADR.
00001'031400            LDA     2,0,3   ;GET ADR. OF NO. OF POSS MODES
00002'050554            STA     2,TSPCA
00003'021000            LDA     0,0,2   ;GET NO. OF POSS. MODES
00004'040553            STA     0,CNTR2
00005'021401            LDA     0,1,3   ;GET ADR. OF POSS MODES TB.
00006'040552            STA     0,TSPPA
00007'040552            STA     0,TSPPX
00010'021402            LDA     0,2,3   ;GET ADR. OF TG. SND. VEL.
00011'040415            STA     0,TGVLA
00012'021403            LDA     0,3,3   ;GET ADR. OF SONO. SND. VEL.
00013'040412            STA     0,SNVLA
00014'021404            LDA     0,4,3   ;GET ADR. OF Z LIMITS TB.
00015'040545            STA     0,ZLIMA
00016'031405            LDA     2,5,3   ;GET ADR. OF SONO. LY. NO.
00017'021000            LDA     0,0,2   ;GET SONO. LY. NO.
00020'040543            STA     0,SONLY
00021'031406            LDA     2,6,3   ;GET ADR. OF TG. LY. NO.
00022'021000            LDA     0,0,2   ;GET TG.LY.NO.
00023'040541            STA     0,TAGLY
00024'006541            JSR     @.FSUB  ;SONO. SND. VEL. - TG. SND. VEL
00025'000000 SNVLA:     0               ;ADR. OF SONO. SND. VEL.
00026'000000 TGVLA:     0               ;ADR. OF TG. SND. VEL.
00027'000166'           TEMA1           ;ADR. OF RESULT
00030'020537            LDA     0,TEMA2 ;GET RESULT
00031'030775            LDA     2,TGVLA ;GET ADR. OF TG. SND. VEL.
00032'101103            MOVL    0,0,SNC ;SKIP IF TG. SND. VEL > SONO. SND. VEL.
00033'030772            LDA     2,SNVLA ;GET ADR. OF SONO. SND. VEL.
00034'050535            STA     2,LTSVA ;STORE ADR. OF LARGER SND. VEL.
00035'030523 LOOP2:     LDA     2,TSPPA ;GET ADR. OF POSS. MODES TB.
00036'025000            LDA     1,0,2   ;GET TOP LAYER NO.
00037'021001            LDA     0,1,2   ;GET BOT. LAYER NO.
00040'044532            STA     1,TPLY
00041'040532            STA     0, BTLY
00042'102520            SUBZL   0,0     ;ONE IN AC0
00043'106400            SUB     0,1     ;TOP LAYER NO. - ONE
00044'030530            LDA     2,DBINC ;GET DATA BASE INCREMENT
00045'020530            LDA     0,.LYVL ;GET ADR. OF LY. SND. VEL. TB.
00046'073301            MUL             ;ADR. OF TOP Z MAX. LIMIT
00047'044475            STA     1,ZTMXA
00050'147000            ADD     2,1     ;ADR. OF TOP Z MIN. LIMIT
00051'044462            STA     1,ZTMNA
00052'020520            LDA     0,TPLY  ;GET TOP LY. NO.
00053'101004            MOV     0,0,SZR ;SKIP IF TOP LY. NO. IS ZERO
00054'000405            JMP     ENTR1   ;JUMP AROUND
00055'024521            LDA     1,MAXZA ;GET ADR. OF LIMIT ON Z MAX.
00056'044466            STA     1,ZTMXA ;ADR. OF TOP Z MAX. LIMIT
00057'020516            LDA     0,.LYVL ;ADR. OF LY. SND. VEL. TB.
00060'040453            STA     0,ZTMNA ;ADR. OF Z MIN LIMIT
00061'024512 ENTR1:     LDA     1,BTLY  ;GET BOT.LY. NO.
```

```
0002  ZLIM
 00062'102520          SUBZL   0,0      ;ONE IN AC0
 00063'106400          SUB     0,1      ;BOT, LY, NO, - ONE
 00064'050510          LDA     2,DBINC  ;GET DATA BASE INCREMENT
 00065'020510          LDA     0,.LYVL  ;GET ADR, OF LY, SND, VEL, TB,
 00066'073301          MUL              ;ADR, OF BOT, Z MIN, LIMIT
 00067'044445          STA     1,ZBMNA
 00070'147000          ADD     2,1      ;ADR, OF BOT, Z MAX, LIMIT
 00071'044454          STA     1,ZBMXA
 00072'020501          LDA     0,BTLY   ;GET BOT, LY, NO,
 00073'024513          LDA     1,FOUR   ;GET FOUR
 00074'106414          SUB#    0,1,SZR  ;SKIP IF BOT, LY, NO,IS FOUR
 00075'000403          JMP     ENTR2    ;JUMP AROUND
 00076'024500          LDA     1,MAXZA  ;GET ADR, OF LIMIT ON Z MAX,
 00077'044446          STA     1,ZBMXA  ;ADR, OF BOT, Z MAX, LIMIT
 00100'020472 ENTR2:   LDA     0,TPLY   ;GET TOP LY,NO,
 00101'030432          LDA     2,ZTMNA  ;GET ADR,, OF TOP Z MIN, LIMIT
 00102'004407          JSR     SUBR1    ;TEST FOR OBJ, IN TOP LY,
 00103'050430          STA     2,ZTMNA  ;ADR, OF TOP Z MIN, LIMIT
 00104'020467          LDA     0,BTLY   ;GET BOT, LY,NO,
 00105'030427          LDA     2,ZBMNA  ;GET ADR,, OF BOT, Z MIN, LIMIT
 00106'004403          JSR     SUBR1    ;TEST FOR OBJ, IN BOT, LY,
 00107'050425          STA     2,ZBMNA  ;ADR, OF BOT, Z MIN, LIMIT
 00110'000422          JMP     ARND1    ;JUMP AROUND SUBR1
 00111'054471 SUBR1:   STA     3,RETUN  ;SAVE RETURN ADR,
 00112'024452          LDA     1,TAGLY  ;GET TG, LY, NO,
 00113'176400          SUB     3,3      ;ZERO IN AC3
 00114'106414          SUB#    0,1,SZR  ;SKIP IF TG,, IN LY,
 00115'000403          JMP     ENTR3    ;TEST LOCATION OF SONO,
 00116'030710          LDA     2,TGVLA  ;GET ADR, OF TG, SND, VEL,
 00117'176520          SUBZL   3,3      ;ONE IN AC3
 00120'024443 ENTR3:   LDA     1,SONLY  ;GET SONO, LY, NO,
 00121'106414          SUB#    0,1,SZR  ;SKIP IF SONO, IN LY,
 00122'000406          JMP     ENTR5    ;JUMP TO END
 00123'175004          MOV     3,3,SZR  ;SKIP IF ONLY SONO, IN LY,
 00124'000403          JMP     ENTR4    ;BOTH TG, AND SONO, IN LY,
 00125'030700          LDA     2,SNVLA  ;GET ADR, OF SONO, SND, VEL
 00126'000402          JMP     ENTR5    ;JUMP TO END
 00127'030442 ENTR4:   LDA     2,LTSVA  ;GET ADR, OF GREATER SND, VEL,
 00130'034452 ENTR5:   LDA     3,RETUN  ;GET RETURN ADR,
 00131'001400          JMP     0,3      ;RETURN
 00132'006433 ARND1:   JSR     @,FSUB   ;TOP Z MIN, - BOT, Z MIN,
 00133'000000 ZTMNA:   0                ;ADR, OF TOP Z MIN, LIMIT
 00134'000000 ZBMNA:   0                ;ADR, OF BOT, Z MIN, LIMIT
 00135'000166'         TEMA1            ;ADR, OF RESULT
 00136'020431          LDA     0,TEMA2  ;GET RESULT
 00137'030775          LDA     2,ZBMNA  ;GET ADR, OF BOT, Z MIN, LIMIT
 00140'101113          MOVL#   0,0,SNC  ;SKIP IF BOT, Z > TOP Z
 00141'030772          LDA     2,ZTMNA  ;GET ADR, OF TOP  Z MIN, LIMIT
 00142'050466          STA     2,ZMNTA  ;ADR, OF LARGER Z MIN, LIMIT
   00143'006422          JSR     @,FSUB   ;TOP Z MAX, - BOT, Z MAX,
 00144'000000 ZTMXA:   0                ;ADR,OF TOP Z MAX, LIMIT
 00145'000000 ZBMXA:   0                ;ADR, OF BOT, Z MAX, LIMIT
 00146'000166'         TEMA1            ;ADR, OF RESULT
 00147'020420          LDA     0,TEMA2  ;GET RESULT
 00150'030774          LDA     2,ZTMXA  ;GET ADR, OF TOP Z MAX, LIMIT
 00151'101113          MOVL#   0,0,SNC  ;SKIP IF BOT, Z >TOP Z
 00152'030773          LDA     2,ZBMXA  ;GET ADR, OF BOT, Z MAX, LIMIT
 00153'050475          STA     2,ZMAXA  ;ADR, OF SMALLER Z MAX, LI ZT
 00154'000434          JMP     ARND2    ;JUMP AROUND DATA
```

LISTING C4 (Continued)

```
00155'000000 RETRN:  0
00156'000000 TSPCA:  0
00157'000000 CNTR2:  0
00160'000000 TSPPA:  0
00161'000000 TSPPX:  0
00162'000000 ZLIMA:  0
00163'000000 SONLY:  0
00164'000000 TAGLY:  0
00165'177777 .FSUB:  FFSB
00166'000000 TEMA1:  0
00167'000000 TEMA2:  0
00170'000000         0
00171'000000 LTSVA:  0
00172'000000 TPLY:   0
00173'000000 BTLY:   0
00174'000003 DBINC:  3
00175'177777 .LYVL:  LYVEL
00176'000177'MAXZA:  MAXZ1
00177'040100 MAXZ1:  040100          ;64 DEC.
00200'077777 MAXZ2:  077777
00201'177777 MAXZ3:  177777
00202'000000 RETUN:  0
00203'000000 CNTR1:  0
00204'177777 .FMUL:  FFML
00205'177777 .FADD:  FFAD
00206'000004 FOUR:   4
00207'000002 TWO:    2
00210'024762 ARND2:  LDA     1,TPLY  ;GET TOP LY. NO.
00211'020762         LDA     0,BTLY  ;GET BOT. LY. NO.
00212'122400         SUB     1,0     ;BOT. LY. NO. - TOP LY. NO.
00213'030774         LDA     2,TWO
00214'142400         SUB     2,0
00215'040766         STA     0,CNTR1 ;LOOP COUNTER
00216'101112         MOVL#   0,0,SZC
00217'000426         JMP     ARND3
00220'101005         MOV     0,0,SNR
00221'000424         JMP     ARND3
00222'030752         LDA     2,DBINC
00223'020752         LDA     0,.LYVL
00224'143000         ADD     2,0
00225'073301         MUL
00226'044403         STA     1,LYVLA
00227'006736 LOOP1:  JSR     @.FSUB  ;Z MIN. LIMIT - LY. SND. VEL.
00230'000000 ZMNTA:  0               ;ADR. OF Z MIN. LIMIT
00231'000000 LYVLA:  0               ;ADR. OF LY. SND. VEL.
00232'000166'        TEMA1           ;ADR. OF RESULT
00233'020734         LDA     0,TEMA2 ;GET RESULT
00234'030775         LDA     2,LYVLA ;GET ADR.OF LY. SND. VEL.
00235'101102         MOVL    0,0,SZC ;SKIP IF Z MIN. > OR = LY. SND. VEL.
00236'050772         STA     2,ZMNTA ;ADR. OF Z MIN. LIMIT
00237'151400         INC     2,2     ;SET UP NEXT LY. SND. VEL. ADR.
00240'151400         INC     2,2
00241'151400         INC     2,2
00242'050767         STA     2,LYVLA
00243'014740         DSZ     CNTR1   ;SKIP AFTER LAST LY. CHECK
00244'000763         JMP     LOOP1   ;TEST NEXT LAYER
00245'030763 ARND3:  LDA     2,ZMNTA ;GET ADR. OF Z MIM. LIMIT
00246'050403         STA     2,ZMINA ;FIX Z MIN. ADR.
00247'006716         JSR     @.FSUB  ;Z MAX. LIMIT - Z MIN. LIMIT
```

LISTING C4 (Continued)

```
0004  ZLIM
 00250'000000 ZMAXA:  0                ;ADR. OF Z MAX. LIMIT
 00251'000000 ZMINA:  0                ;ADR. OF Z MIN. LIMIT
 00252'000166'        TEMA1            ;ADR. OF RESULT
 00253'020714         LDA     0,TEMA2  ;GET RESULT
 00254'030704         LDA     2,TSPPA  ;GET ADR. OF POSS. MODES TB.
 00255'101113         MOVL#   0,0,SNC  ;SKIP IF Z MIN. > Z MAX.
 00256'000407         JMP     ENTR6    ;LIMITS ARE ALLOWED
 00257'016677 ELIMR:  DSZ     @TSPCA
 00260'101000         MOV     0,0
 00261'151400         INC     2,2
 00262'151400         INC     2,2
 00263'050675         STA     2,TSPPA
 00264'000437         JMP     ENTR7
 00265'021000 ENTR6:  LDA     0,0,2
 00266'025001         LDA     1,1,2
 00267'151400         INC     2,2
 00270'151400         INC     2,2
 00271'050667         STA     2,TSPPA
 00272'030667         LDA     2,TSPPX
 00273'041000         STA     0,0,2
 00274'045001         STA     1,1,2
 00275'151400         INC     2,2
 00276'151400         INC     2,2
 00277'050662         STA     2,TSPPX
 00300'034662         LDA     3,ZLIMA  ;GET ADR. OF Z LIMIT TB.
 00301'030747         LDA     2,ZMAXA  ;GET Z MAX. LIMIT
 00302'021000         LDA     0,0,2    ;STORE DATA IN Z LIMITS TB.
 00303'041400         STA     0,0,3
 00304'021001         LDA     0,1,2
 00305'041401         STA     0,1,3
 00306'021002         LDA     0,2,2
 00307'041402         STA     0,2,3
 00310'030741         LDA     2,ZMINA  ;GET Z MIN. LIMIT
 00311'021000         LDA     0,0,2    ;STORE DATA IN Z LIMIT TB.
 00312'041403         STA     0,3,3
 00313'021001         LDA     0,1,2
 00314'041404         STA     0,4,3
 00315'021002         LDA     0,2,2
 00316'041405         STA     0,5,3
 00317'030655         LDA     2,DBINC  ;GET DATA BLOCK INCREMENT
 00320'157000         ADD     2,3
 00321'157000         ADD     2,3
 00322'054640         STA     3,ZLIMA
 00323'014634 ENTR7:  DSZ     CNTR2    ;SKIP IF THIS WAS LAST MODE
 00324'002407         JMP     @,LOP2   ;DO NEXT MODE
 00325'034630 ENDRR:  LDA     3,RETRN  ;GET RETURN ADR.
 00326'001407         JMP     7,3      ;RETURN
 00327'000000 TEMB1:  0
 00330'000000         0
 00331'000000         0
 00332'000327'TEMPB:  TEMB1
 00333'000035',LOP2:  LOOP2
                      .END
```

LISTING C4 (Continued)

MNMX SUBROUTINE

1. The MNMX subroutine computes both the horizontal range between the target and sonobuoy and also the minimum and maximum number of ray path half cycles that may exist within each mode in A1PP. This subroutine also forms the partial code word table.

2. PROPM

3.
```
        JSR@ .MNMX
        .SnXH
        .TmXH
        A1PCT
        A1PP
        A1ZL
        A1MM
        A1HR
        A1CW
    .
    .
    .
.MNMX: MNMX
```

4. FPMP, FIN1, FIN2, and CPHR

5. .SnXH, .TmXH, A1PCT, A1PP, A1ZL, and CRG1

6. A1MM, A1HR, and A1CW

7. See Figure C5.

8. See Listing C5.

9. a. This subroutine sets up a partial central data table which contains data needed by the FIN1 and FIN2 subroutines to calculate the half cycle ocean parameters for a given ray path.

   b. A partial code word is a 16 bit word which contains the following information about a ray path:

      BITS 0 through 2--TPNUM (0 to 3)

      BITS 3 through 5--BTNUM (1 to 4)

   This information is extracted directly from A1PP.

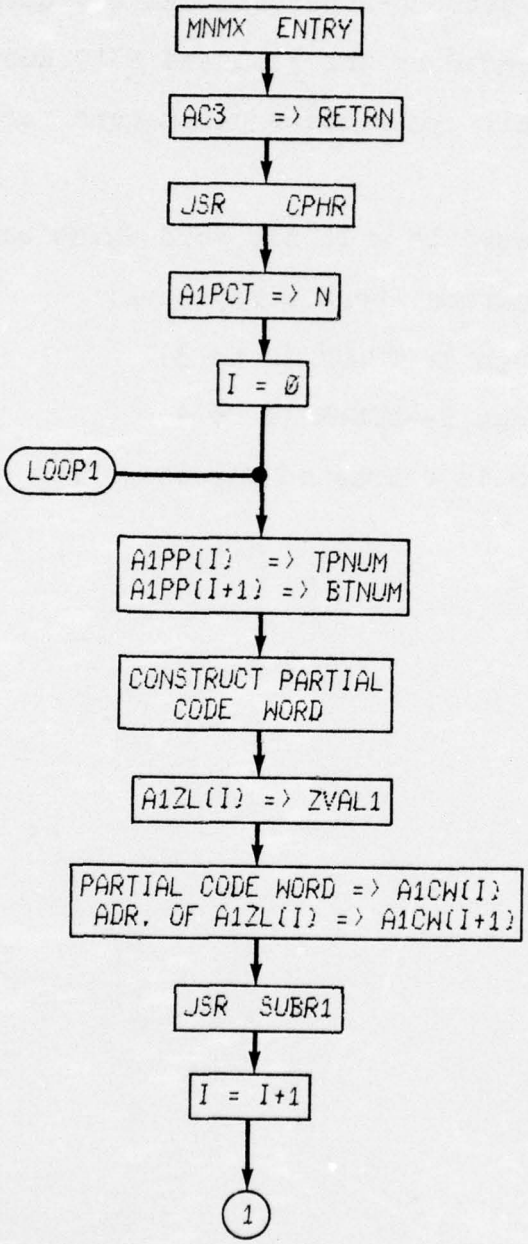

MNMX ENTRY
AC3 => RETRN
JSR CPHR
A1PCT => N
I = Ø
LOOP1
A1PP(I) => TPNUM
A1PP(I+1) => BTNUM
CONSTRUCT PARTIAL CODE WORD
A1ZL(I) => ZVAL1
PARTIAL CODE WORD => A1CW(I)
ADR. OF A1ZL(I) => A1CW(I+1)
JSR SUBR1
I = I+1
1

FIG. C5

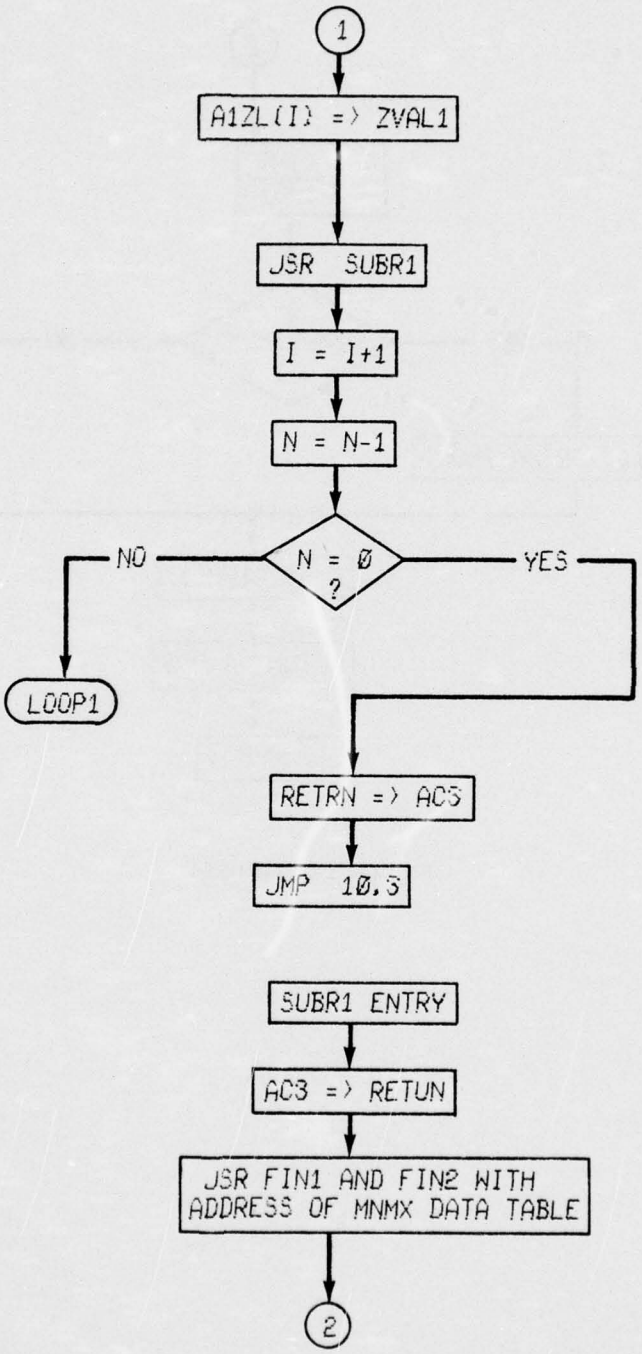


FIG. C5 (CONTINUED)

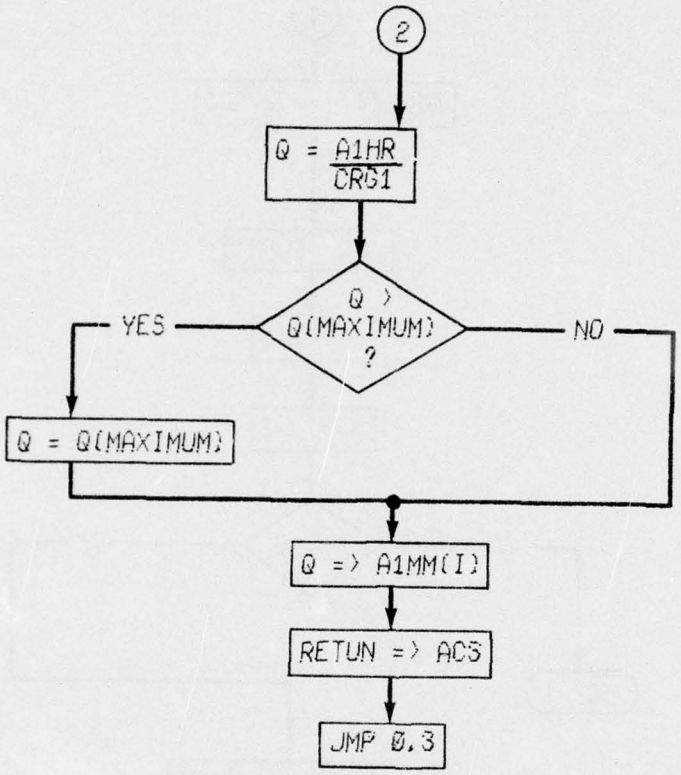


FIG. C5 (CONTINUED)

```
                        .NREL
                        .TITL   MNMX    ;05/01/74
        000010          .RDX    8
                        .ENT    MNMX
                        .EXTN   FFAD
                        .EXTN   FFSB
                        .EXTN   FFXD
                        .EXTN   FFDV
                        .EXTN   FIN1
                        .EXTN   FIN2
                        .EXTN   CRG1
                        .EXTN   CPHR
00000'000003 DBINC:     3
00001'000000 PPCNT:     0
00002'000000 PPATA:     0
00003'000000 ZLIMA:     0
00004'000000 PPZLA:     0
00005'000161',RETN:     RETRN
00006'056777 MNMX:      STA     @3,.RETN;SAVE RETURN ADR.
00007'021400            LDA     0,0,3   ;GET ADR. OF SONO. TB.
00010'040422            STA     0,SNXAD ;ADR. OF SONO. X
00011'021401            LDA     0,1,3   ;GET ADR. OF TARGET TB.
00012'040421            STA     0,TGXAD ;ADR. OF TG. X
00013'021402            LDA     2,2,3   ;GET ADR. OF NO.POSS. MODES
00014'021000            LDA     0,0,2   ;GET NO.OF POSS. MODES
00015'040764            STA     0,PPCNT
00016'021403            LDA     0,3,3   ;GET ADR.OF POSS. MODES TB.
00017'040763            STA     0,PPATA
00020'021404            LDA     0,4,3   ;GET ADR. OF Z LIMIT TB.
00021'040762            STA     0,ZLIMA
00022'021405            LDA     0,5,3   ;GET ADR. OF MN. - MX. TB.
00023'040522            STA     0,MNXTA
00024'021406            LDA     0,6,3   ;GET ADR. OF ACT. HOR. RNG.
00025'040407            STA     0,TSHRA
00026'040500            STA     0,TSHRB
00027'021407            LDA     0,7,3   ;GET ADR. OF PARTIAL CD. WD. TB.
00030'040754            STA     0,PPZLA
00031'006533            JSR     @,CPHR
00032'000000 SNXAD:     0
00033'000000 TGXAD:     0
00034'000000 TSHRA:     0
00035'030745            LDA     2,PPATA ;GET ADR. OF POSS. MODES TB.
00036'021000 LOOP1:     LDA     0,0,2   ;GET TOP LAYER NO.
00037'025001            LDA     1,1,2   ;GET BOT. LAYER NO.
00040'040547            STA     0,TPNUM
00041'044547            STA     1,BTNUM
00042'103120            ADDZL   0,0     ;MAKE PARTIAL CODE WORD
00043'101120            MOVZL   0,0
00044'123120            ADDZL   1,0
00045'101120            MOVZL   0,0
00046'115300            MOVS    0,3
00047'030734            LDA     2,ZLIMA ;GET Z LIMITS ADR.
00050'145000            MOV     2,1
00051'021000            LDA     0,0,2
00052'040532            STA     0,ZVAL1
00053'021001            LDA     0,1,2
00054'040531            STA     0,ZVAL2
00055'021002            LDA     0,2,2
```

```
0002  MNMX
 00056'040530          STA     0.ZVAL3
 00057'030725          LDA     2.PPZLA ;GET ADR. OF PARTIAL CD. WD. TB.
 00060'055000          STA     3.0.2   ;STORE PARTIAL CODE WORD
 00061'045001          STA     1.1.2   ;STORE ADR. OF Z LIMITS
 00062'151400          INC     2.2     ;SET UP NEXT ADR.
 00063'151400          INC     2.2
 00064'050720          STA     2.PPZLA
 00065'004433          JSR     SUBR1   ;FIND MN. - MX. HALF CYC.
 00066'024712          LDA     1.DBINC ;GET DATA BASE INCREMENT
 00067'030714          LDA     2.ZLIMA ;GET Z LIMITS ADR.
 00070'133000          ADD     1.2     ;SET UP NEXT Z LIMITS ADR.'S
 00071'021000          LDA     0.0.2
 00072'040512          STA     0.ZVAL1
 00073'021001          LDA     0.1.2
 00074'040511          STA     0.ZVAL2
 00075'021002          LDA     0.2.2
 00076'040510          STA     0.ZVAL3
 00077'133000          ADD     1.2
 00100'050703          STA     2.ZLIMA
 00101'006454          JSR     @.FADD
 00102'000204'         ZVAL1
 00103'000156'         FGA1
 00104'000204'         ZVAL1
 00105'004413          JSR     SUBR1   ;FIND MN. - MX. HALF CYC.
 00106'014673          DSZ     PPCNT   ;SKIP   IF ALL MODES CHECKED
 00107'000402          JMP     .+2     ;SKIP
 00110'000406          JMP     ENDRR   ;END
 00111'030671          LDA     2.PPATA ;GET ADR. OF POSS. MODES TB.
 00112'151400          INC     2.2     ;SET UP NEXT ADR.
 00113'151400          INC     2.2
 00114'050666          STA     2.PPATA
 00115'000721          JMP     LOOP1   ;DO NEXT MODE
 00116'034443 ENDRR:   LDA     3.RETRN ;GET RETURN ADR.
 00117'001410          JMP     10.3    ;RETURN
 00120'054443 SUBR1:   STA     3.RETUN ;SAVE RETURN ADR.
 00121'006444          JSR     @.FIN1  ;COMPUTE HALF CYC. HOR. RNG.
 00122'000161'         RETRN
 00123'006443          JSR     @.FIN2
 00124'000161'         RETRN
 00125'006442          JSR     @.FDIV  ;(ACT. HOR. RNG.)/(HALF CYC.RNG.
 00126'000000 TSHRB:   0               ;ADR. OF ACT. HOR. RNG.
 00127'177777          CRG1            ;ADR. OF HALF CYC. HOR. RNG.
 00130'000171'         TEMA1           ;ADR. OF RESULT
 00131'006451          JSR     @.FSUB  ;NO. OF HALF CYC. - MX. NO.
 00132'000171'         TEMA1           ;ADR. OF COMPUTED NO. OF HALF CYC.
 00133'000177'         MAXL1           ;ADR. OF MX. LIMIT NO.
 00134'000174'         TEMB1           ;ADR. OF RESULT
 00135'020440          LDA     0.TEMB2 ;GET RESULT
 00136'030432          LDA     2.MAXLA ;GET ADR. OF MX. LIMIT NO.
 00137'101102          MOVL    0.0.SZC ;SKIP IF LIMIT REACHED
 00140'030442          LDA     2.TEMPA ;GET ADR. OF COMPUTED RESULT
 00141'050402          STA     2.TEMPF ;STORE THIS ADR.
 00142'006441          JSR     @.FXDP  ;FIX POINT THE NO.OF CYC.
 00143'000000 TEMPF:   0               ;ADR. OF NO. OF HALF CYCLES
 00144'000020          20              ;B16 DP
 00145'000000 MNXTA:   0               ;ADR. OF MN. - MX. TB.
 00146'030777          LDA     2.MNXTA ;GET ADR. OF MN. - MX. TB.
 00147'151400          INC     2.2     ;SET UP NEXT ADR.
 00150'151400          INC     2.2
```

LISTING C5 (Continued)

```
0003  MNMX
 00151'050774          STA     2,MNXTA
 00152'101000          MOV     0,0     ;JSR    3
 00153'034410          LDA     3,RETUN ;GET RETURN ADR.
 00154'001400          JMP     0,3     ;RETURN
 00155'177777 .FADD:   FFAD
 00156'037762 FGA1:    037762
 00157'077777          077777
 00160'177777          177777
 00161'000000 RETRN:   0
 00162'177777 .FSUB:   FFSB
 00163'000000 RETUN:   0
 00164'177777 .CPHR:   CPHR
 00165'177777 .FIN1:   FIN1
 00166'177777 .FIN2:   FIN2
 00167'177777 .FDIV:   FFDV
 00170'000177'MAXLA:   MAXL1
 00171'000000 TEMA1:   0
 00172'000000          0
 00173'000000          0
 00174'000000 TEMB1:   0
 00175'000000 TEMB2:   0
 00176'000000          0
 00177'040013 MAXL1:   40013
 00200'040000          40000
 00201'000000          0
 00202'000171'TEMPA:   TEMA1
 00203'177777 .FXDP:   FFXD
 00204'000000 ZVAL1:   0
 00205'000000 ZVAL2:   0
 00206'000000 ZVAL3:   0
 00207'000000 TPNUM:   0
 00210'000000 BTNUM:   0
 00211'000000          0
 00212'000000          0
 00213'000000          0
 00214'000000 FN1SK:   0
 00215'000000 FN2SK:   0
 00216'000000          0
                       .END
```

LISTING C5 (Continued)

NRMD SUBROUTINE

1. The NRMD subroutine calls the three ray path solution subroutines for the three layer ocean model. This subroutine also sets up a central data base and computes the square of the target and sonobuoy sound velocities.

2. PROPM

3.
```
          JSR@ NRMD
          SLY1
          SLYA
          SVL1
          SVLA
          A1HR
          A1PCT
          A1CW
          A1MM
          mnNLP
          mnLPW
          m1NBS
          m1BST
          mnNBM
          mnBMS
    .
    .
    .
.NRMD:    NRMD
```

4. FPMP, N1, N2, and N3

5. SLY1, SLYA, SVL1, SVLA, A1HR, A1PCT, A1CW, A1MM

   mnNLP, mnLPW, m1NBS, m1BST, mnNBM, and mnBMS.

6. SNSQ1 and TGSQ1

7. See Figure C6.

8. See Listing C6.

9. The central data base contains most of the data needed to calculate the ocean parameters for a given ray path. The two flags FN1SK and FN2SK control parts of the calculation in the FIN1 and FIN2 subroutines.

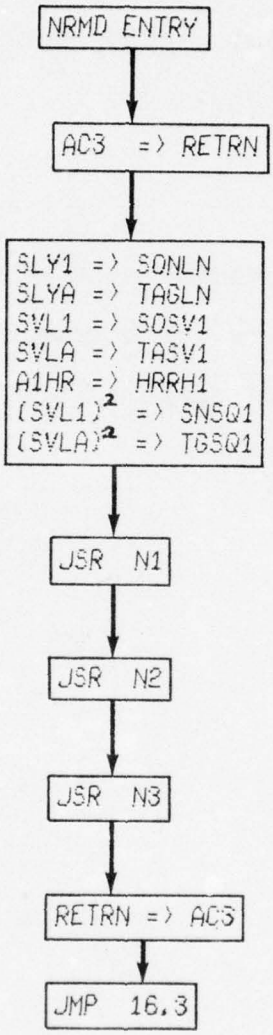
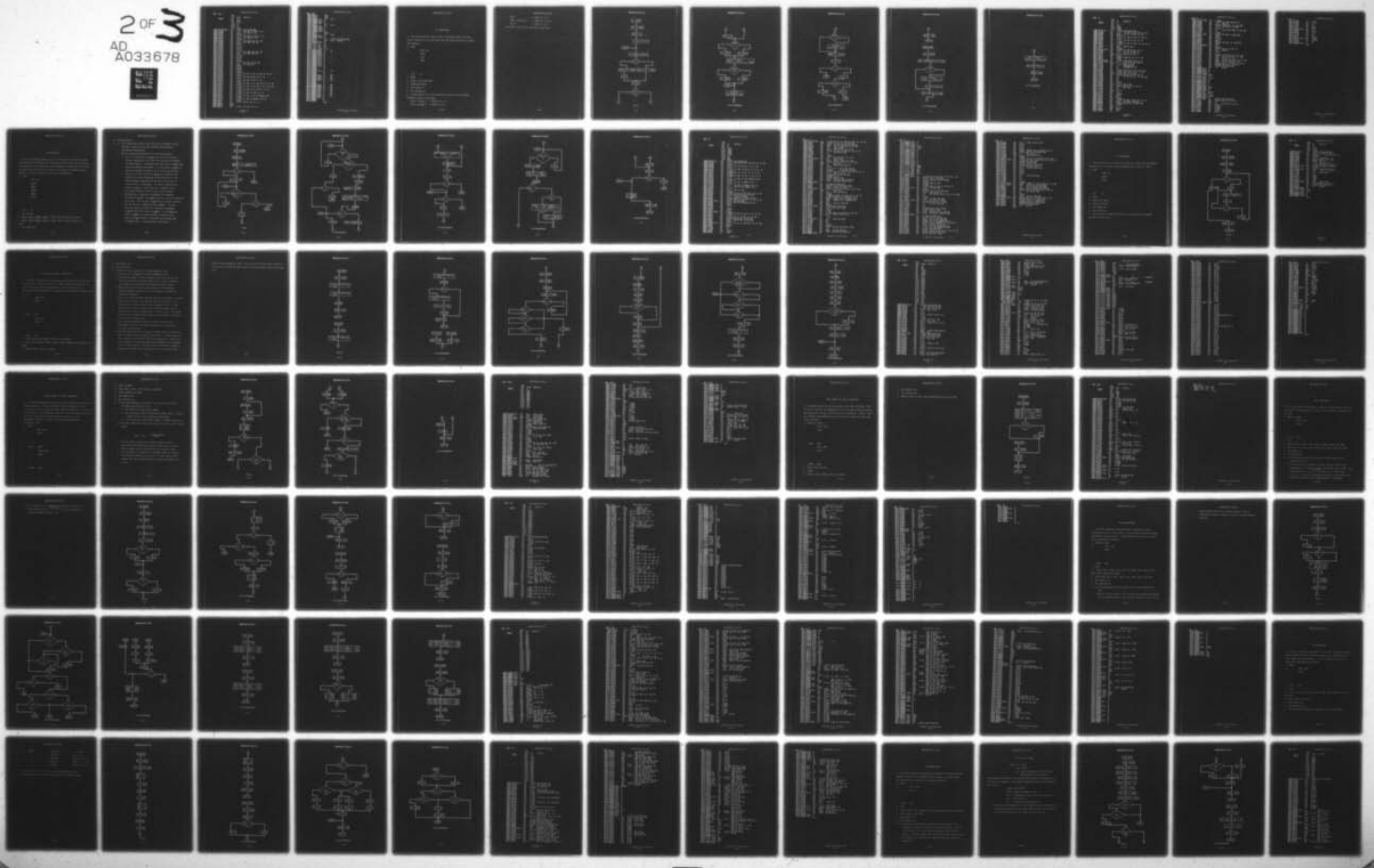

NRMD ENTRY
AC3 => RETRN
SLY1 => SQNLN
SLYA => TAGLN
SVL1 => SQSV1
SVLA => TASV1
A1HR => HRRH1
(SVL1)2 => SNSQ1
(SVLA)2 => TGSQ1
JSR N1
JSR N2
JSR N3
RETRN => AC3
JMP 16,3

FIG. C6

AD-A033 678 NAVAL SURFACE WEAPONS CENTER WHITE OAK LAB SILVER SP--ETC F/G 9/2
REAL TIME THREE LAYER OCEAN MODEL.(U)
APR 76 P J CRAUN

UNCLASSIFIED NSWC/WOL/TR-75-115 NL

2 OF 2
AD A033678



```
---
0001  NRMD
                        .NREL
                        .TITL   NRMD    ;05/08/74
        000010          .RDX    8
                        .ENT    NRMD
                        .ENT    BGDAT
                        .EXTN   N1
                        .EXTN   N2
                        .EXTN   N3
                        .EXTN   FFSQ
00000'054503 NRMD:      STA     3,RETRN ;SAVE RETURN ADR
00001'031400            LDA     2,0,3   ;GET ADR. OF SONO. LY. NO.
00002'021000            LDA     0,0,2   ;GET SONO. LY. NO.
00003'040525            STA     0,SONLN
00004'031401            LDA     2,1,3   ;GET ADR. OF TARG. LY. NO.
00005'021000            LDA     0,0,2   ;GET TARGET LY. NO.
00006'040523            STA     0,TAGLN
00007'031402            LDA     2,2,3   ;GET SONO, SND. VEL. ADR.
00010'021000            LDA     0,0,2   ;GET SONO. SND. VEL.
00011'040503            STA     0,SOSV1
00012'021001            LDA     0,1,2
00013'040502            STA     0,SOSV2
00014'021002            LDA     0,2,2
00015'040501            STA     0,SOSV3
00016'031403            LDA     2,3,3   ;GET TARG. SND. VEL. ADR.
00017'021000            LDA     0,0,2   ;GET TARG. SND. VEL.
00020'040477            STA     0,TASV1
00021'021001            LDA     0,1,2
00022'040476            STA     0,TASV2
00023'021002            LDA     0,2,2
00024'040475            STA     0,TASV3
00025'031404            LDA     2,4,3   ;GET ADR. OF HOR. RNG.
00026'021000            LDA     0,0,2   ;GET HOR. RNG.
00027'040462            STA     0,HRRH1
00030'021001            LDA     0,1,2
00031'040461            STA     0,HRRH2
00032'021002            LDA     0,2,2
00033'040460            STA     0,HRRH3
00034'031405            LDA     2,5,3   ;GET ADR. OF NO. OF PART. CD. WD. TB.
00035'050430            STA     2,TSNPC
00036'031406            LDA     2,6,3   ;GET ADR.OFPART. CD. WD. TB.
00037'050427            STA     2,TSCW
00040'031407            LDA     2,7,3   ;GET ADR. OF MN. MX. TB.
00041'050426            STA     2,TSMM
00042'031410            LDA     2,10,3  ;GET ADR. OF NO. LAST POSS. PH. CD. WD.
00043'050426            STA     2,TSNLP
00044'031411            LDA     2,11,3  ;GET ADR. OF LAST POSS. PH. CD. WD. TB.
00045'050425            STA     2,TSLPW
00046'031412            LDA     2,12,3  ;GET ADR. OF NO. OF BASIC SOL. TB
00047'050430            STA     2,TSNBS
00050'031413            LDA     2,13,3  ;GET ADR. OF BASIC SOL. TB.
00051'050427            STA     2,TSBST
00052'031414            LDA     2,14,3  ;GET ADR. OF NO. OF BOMBING SITES
00053'050420            STA     2,TSNBM
00054'031415            LDA     2,15,3  ;GET ADR. OF BOMBING SITES TB.
00055'050417            STA     2,TSBMS
00056'006431            JSR     @.FSQR  ;(SONO. SND. VEL.) ^2
00057'000114'           SOSV1
00060'000122'           SNSQ1
00061'006426            JSR     @.FSQR  ;(TG. SND. VEL.)^2
```

```
0002  NRMD
 00062'000117'          TASV1
 00063'000125'          TGSQ1
 00064'006420           JSR     @.N1
 00065'000000 TSNPC:    0
 00066'000000 TSCW:     0
 00067'000000 TSMM:     0
 00070'006415           JSR     @.N2
 00071'000000 TSNLP:    0
 00072'000000 TSLPW:    0
 00073'000000 TSNBM:    0
 00074'000000 TSBMS:    0
 00075'000110'          BGDAT
 00076'006410           JSR     @.N3
 00077'000000 TSNBS:    0
 00100'000000 TSBST:    0
 00101'034402           LDA     3,RETRN ;GET RETURN ADR.
 00102'001416           JMP     16,3    ;RETURN
 00103'000000 RETRN:    0
 00104'177777 .N1:      N1
 00105'177777 .N2:      N2
 00106'177777 .N3:      N3
 00107'177777 .FSQR:    FFSQ
 00110'000000 BGDAT:    0       ;0
 00111'000000 HRRH1:    0       ;1
 00112'000000 HRRH2:    0
 00113'000000 HRRH3:    0
 00114'000000 SOSV1:    0       ;4
 00115'000000 SOSV2:    0
 00116'000000 SOSV3:    0
 00117'000000 TASV1:    0       ;7
 00120'000000 TASV2:    0
 00121'000000 TASV3:    0
 00122'000000 SNSQ1:    0
 00123'000000           0
 00124'000000           0
 00125'000000 TGSQ1:    0       ;15
 00126'000000           0
 00127'000000           0
 00130'000000 SONLN:    0       ;20
 00131'000000 TAGLN:    0       ;21
 00132'000000 CODEW:    0       ;22
 00133'000000 ZVAL1:    0       ;23
 00134'000000           0
 00135'000000           0
 00136'000000 TPNUM:    0       ;26
 00137'000000 BTNUM:    0       ;27
 00140'000000 DIRMD:    0       ;30
 00141'000000 SGNDV:    0       ;31
 00142'000000 NUMCY:    0       ;32
 00143'000001 FN1SK:    1       ;33
 00144'000000 FN2SK:    0       ;34
 00145'000000 NONRL:    0       ;35
 00146'000000 ZMAX1:    0
 00147'000000           0
 00150'000000           0
                        .END
```

LISTING C6 (Continued)

N1 SUBROUTINE

1. The N1 subroutine forms a table of possible path code words which contains all the ray paths that may exist between the target and sonobuoy.

2. NRMD

3.
```
          JSR@ .N1
          A1PCT
          A1CW
          A1MM
            .
            .
            .
    .N1:  N1
```

4. NONE

5. A1PCT, A1CW, and A1MM

6. TSNPW and TSPCW

7. See Figure C7.

8. See Listing C7.

9. A code word is a 16 bit word which contains the following information about a ray path:

    BITS 0 through 2 -- TPNUM (0 to 3)

    BITS 3 through 5 -- BTNUM (1 to 4)

BIT 6 -- DIRMD (1 or 0)

BITS 7 through 14 -- NUMCY (-1 to 127)

BIT 15 -- SGNDV (1 or 0)

with BIT 0 as the left most bit of the word.

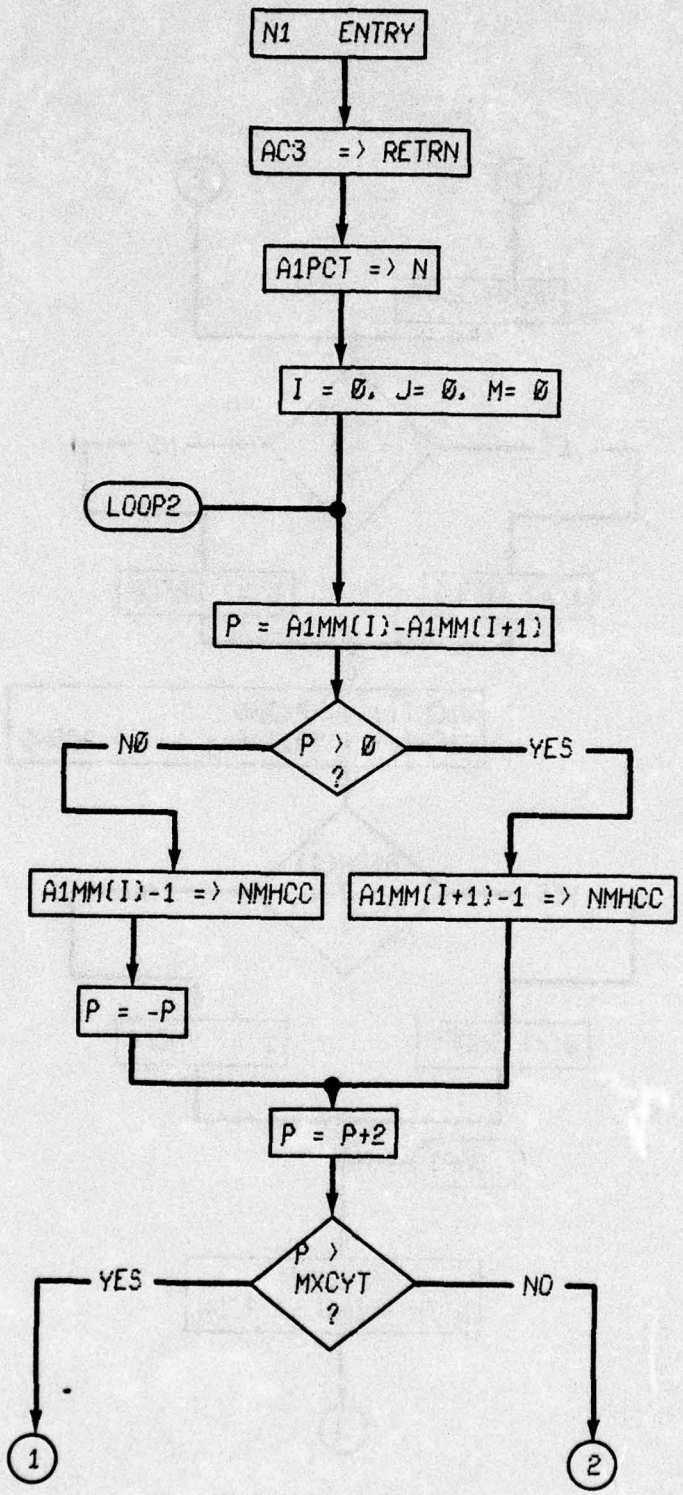

N1 ENTRY
AC3 => RETRN
A1PCT => N
I = Ø, J= Ø, M= Ø
LOOP2
P = A1MM(I)-A1MM(I+1)
P > Ø ?
NØ
YES
A1MM(I)-1 => NMHCC
A1MM(I+1)-1 => NMHCC
P = -P
P = P+2
P > MXCYT ?
YES
NO
1
2

FIG. C7

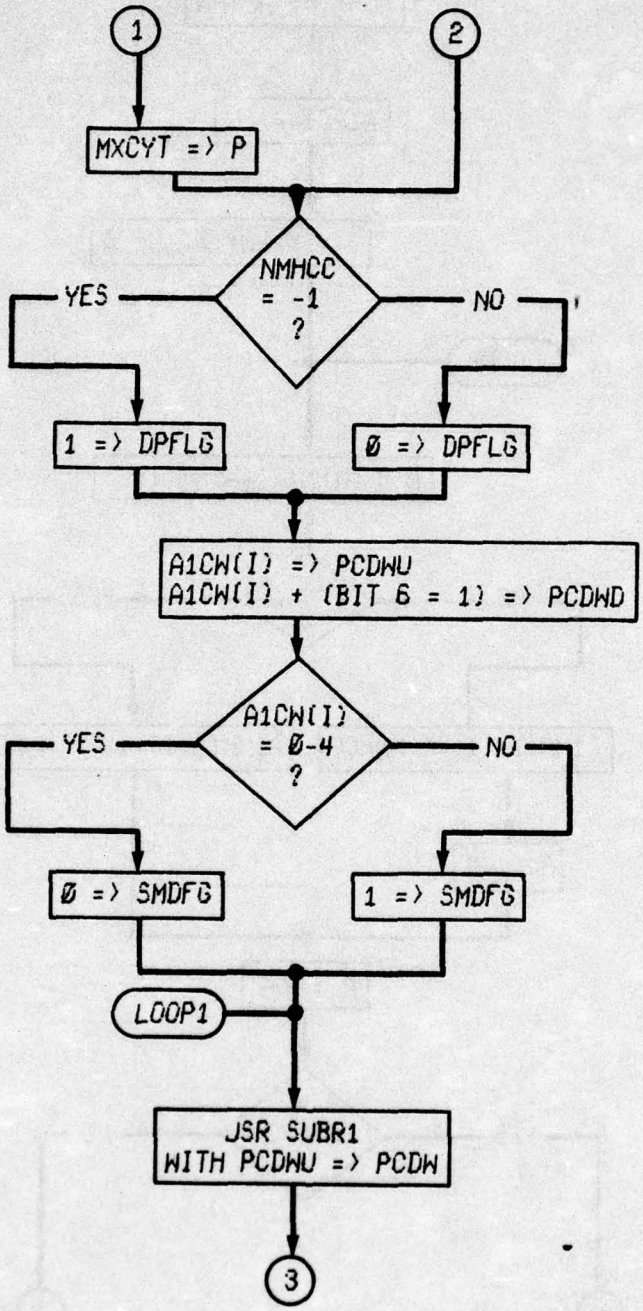


FIG. C7 (CONTINUED)

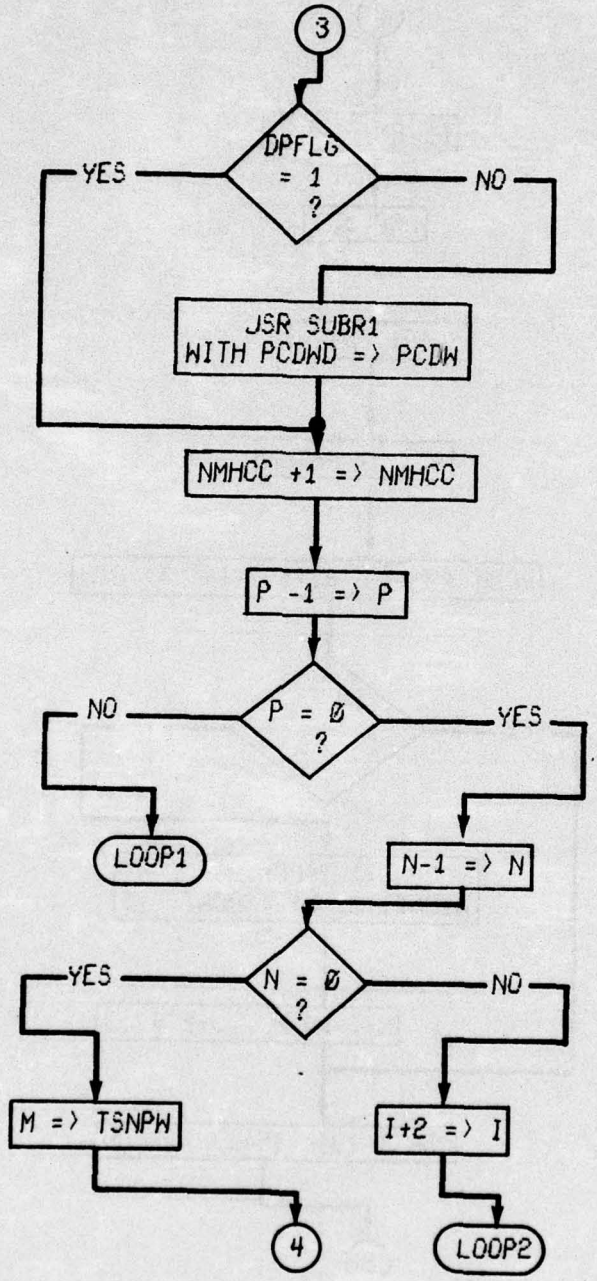


FIG. C7 (CONTINUED)

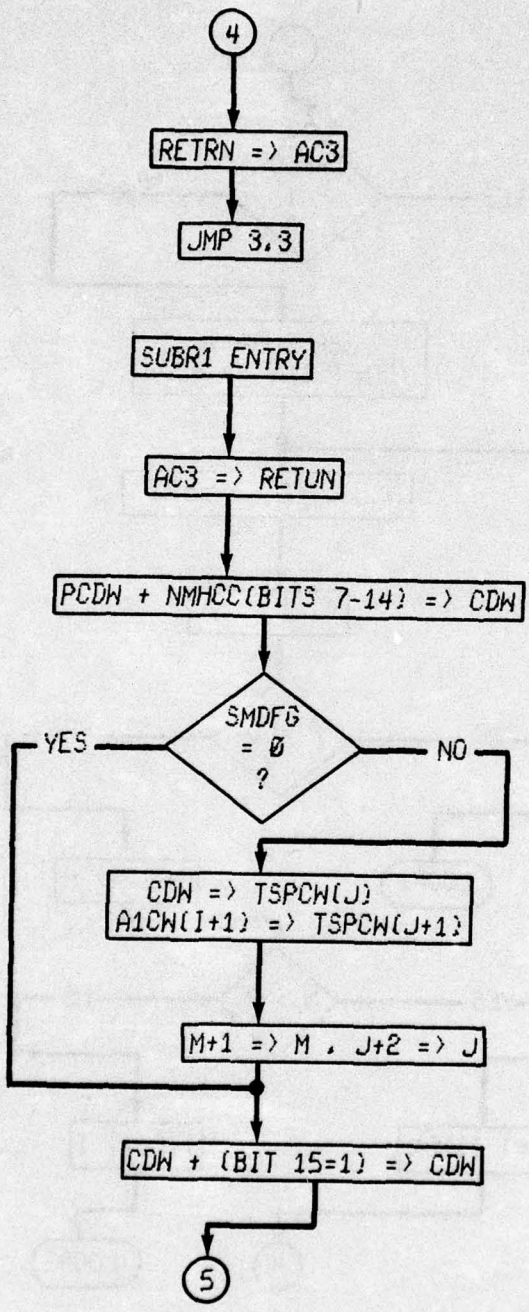


FIG. C7 (CONTINUED)

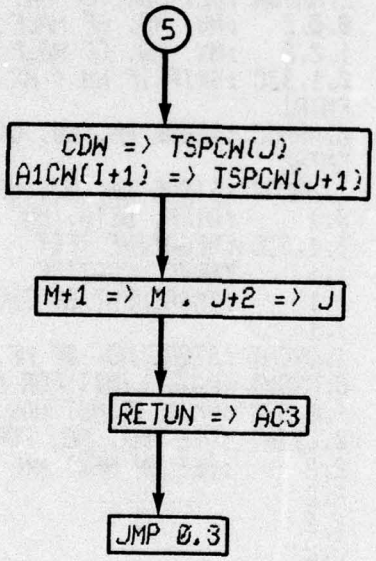


FIG. C7 (CONTINUED)

```
---
0001  N1
                        .NREL
                        .TITL   N1      ;05/09/74
        000010          .RDX    8
                        .ENT    N1
                        .ENT    MXCYT
                        .EXTN   TSNPW
                        .EXTN   TSPCW
00000'054523 N1:        STA     3,RETRN ;SAVE RETURN ADR.
00001'031400            LDA     2,0,3   ;GET ADR. OF NO. PART. CD. WDS.
00002'021000            LDA     0,0,2   ;GET NO. OF PART. CD. WDS.
00003'040521            STA     0,NOPCW
00004'031401            LDA     2,1,3   ;GET ADR. OF PART. CD. WD. TB.
00005'050520            STA     2,PCWTA
00006'031402            LDA     2,2,3   ;GET ADR. OF MN.- MX. TB.
00007'050517            STA     2,MMTBA
00010'030517            LDA     2,.PPCW ;GET ADR. OF POSS. PH. CD. WD. TB.
00011'050517            STA     2,PPCWT
00012'102400            SUB     0,0     ;ZERO IN AC0
00013'040517            STA     0,NPPCW
00014'030512 LOOP2:     LDA     2,MMTBA ;GET ADR. OF MN. - MX. TB
00015'021000            LDA     0,0,2   ;MN. NO. OF HALF CYC.
00016'025002            LDA     1,2,2   ;MX. NO. OF HALF CYC.
00017'106512            SUBL#   0,1,SZC ;SKIP IF MN < MX
00020'000403            JMP     ENTR1
00021'040512            STA     0,NMHCC ;STORE MN. NO. OF HF. CYC.
00022'000402            JMP     ENTR2
00023'044510 ENTR1:     STA     1,NMHCC ;STORE MN. NO. OF HF. CYC.
00024'106400 ENTR2:     SUB     0,1     ;DIFF. BETW. MN. AND MX.
00025'125112            MOVL#   1,1,SZC ;NEGATIVE TEST
00026'124400            NEG     1,1     ;MAKE NEGATIVE
00027'125400            INC     1,1     ;INCREMENT BY TWO
00030'125400            INC     1,1
00031'044503            STA     1,CYCNT ;STORE NO. OF HF. CYC TO TEST
00032'020503            LDA     0,MXCYT ;MAX. LIMIT FOR NO. TO TEST
00033'122512            SUBL#   1,0,SZC ;SKIP IF NOT MAX.
00034'040500            STA     0,CYCNT ;USE MAX. NO. FOR TESTING
00035'151400            INC     2,2     ;SET UP NEXT MN. - MX. TB. ADR.
00036'151400            INC     2,2
00037'151400            INC     2,2
00040'151400            INC     2,2
00041'050465            STA     2,MMTBA
00042'102520            SUBZL   0,0     ;ONE IN AC0
00043'030470            LDA     2,NMHCC ;GET MN. NO. OF HF. CYC.
00044'112400            SUB     0,2     ;SUB. ONE
00045'176400            SUB     3,3
00046'151112            MOVL#   2,2,SZC
00047'175400            INC     3,3
00050'054473            STA     3,DPFLG
00051'020471            LDA     0,MASK
00052'113400            AND     0,2
00053'050460            STA     2,NMHCC
00054'030451            LDA     2,PCWTA ;GET ADR. OF PART. CD. WD. TB.
00055'021000            LDA     0,0,2   ;GET PART. CODE WORD
00056'040460            STA     0,PCDWU ;STORE PART. UP CODE WORD
00057'024465            LDA     1,SMDCW
00060'176520            SUBZL   3,3
00061'106414            SUB#    0,1,SZR
00062'000402            JMP     ARND5
00063'176400            SUB     3,3
```

```
0002  N1
 00064'054461 ARND5:  STA     3,SMDFG
 00065'024452         LDA     1,DNDRB ;GET DOWN DIRECTION BIT
 00066'123000         ADD     1,0     ;ADD BIT
 00067'040451         STA     0,PCDWD ;STORE PART. DN. CODE WORD
 00070'035001         LDA     3,1,2   ;GET ADR. OF Z LIMITS
 00071'054450         STA     3,ZLIMA
 00072'151400         INC     2,2     ;SET UP NEXT PART. CD. WD. ADR.
 00073'151400         INC     2,2
 00074'050431         STA     2,PCWTA
 00075'020441 LOOP1:  LDA     0,PCDWU ;GET PART. UP CODE WORD
 00076'004450         JSR     SUBR1
 00077'020444         LDA     0,DPFLG
 00100'101004         MOV     0,0,SZR
 00101'000403         JMP     ARND1
 00102'020436         LDA     0,PCDWD ;GET PART. DN. CODE WORD
 00103'004443         JSR     SUBR1
 00104'102400 ARND1:  SUB     0,0
 00105'040436         STA     0,DPFLG
 00106'020425         LDA     0,NMHCC ;GET NO. OF HALF CYC.
 00107'101400         INC     0,0     ;ADD ONE
 00110'024432         LDA     1,MASK
 00111'123400         AND     1,0
 00112'040421         STA     0,NMHCC ;SET UP NEXT NO. OF HF. CYC.
 00113'014421         DSZ     CYCNT   ;SKIP IF LAST HF. CYC. DONE
 00114'000761         JMP     LOOP1   ;DO NEXT HF. CYC.
 00115'014407         DSZ     NOPCW   ;SKIP IF LAST PART. CD. WD. DONE
 00116'000676         JMP     LOOP2   ;DO NEXT PARTIAL CD. WD.
 00117'020413         LDA     0,NPPCW ;GET NO. OF POSS. PH. CD. WD.
 00120'042411         STA     @0,NPCWA;STORE NO. IN DATA TB
 00121'034402         LDA     3,RETRN ;GET RETURN ADR.
 00122'001403         JMP     3,3     ;RETURN
 00123'000000 RETRN:  0
 00124'000000 NOPCW:  0
 00125'000000 PCWTA:  0
 00126'000000 MMTBA:  0
 00127'177777 .PPCWT: TSPCW
 00130'000000 PPCWT:  0
 00131'17777  NPCWA:  TSNPW
 00132'000000 NPPCW:  0
 00133'000000 NMHCC:  0
 00134'000000 CYCNT:  0
 00135'000004 MXCYT:  4
 00136'000000 PCDWU:  0
 00137'001000 DNDRB:  1000
 00140'000000 PCDWD:  0
 00141'000000 ZLIMA:  0
 00142'000377 MASK:   000377
 00143'000000 DPFLG:  0
 00144'010000 SMDCW:  010000
 00145'000000 SMDFG:  0
 00146'054427 SUBR1:  STA     3,RETUN ;SAVE RETURN ADR.
 00147'024764         LDA     1,NMHCC ;GET NO. OF HF. CYC.
 00150'125120         MOVZL   1,1
 00151'123000         ADD     1,0     ;ADD IN NO. OF HF. CYC.
 00152'030756         LDA     2,PPCWT
 00153'024766         LDA     1,ZLIMA
 00154'034771         LDA     3,SMDFG
 00155'175005         MOV     3,3,SNR
 00156'000406         JMP     SOLND
```

LISTING C7 (Continued)

```
0003  N1
  00157'041000           STA     0,0,2
  00160'045001           STA     1,1,2
  00161'151400           INC     2,2
  00162'151400           INC     2,2
  00163'010747           ISZ     NPPCW
  00164'101400 SOLND:    INC     0,0
  00165'041000           STA     0,0,2
  00166'045001           STA     1,1,2
  00167'151400           INC     2,2
  00170'151400           INC     2,2
  00171'010741           ISZ     NPPCW
  00172'050736 SUBEN:    STA     2,PPCWT
  00173'034402           LDA     3,RETUN
  00174'001400           JMP     0,3
  00175'000000 RETUN:    0
                         .END
```

LISTING C7 (Continued)

N2 SUBROUTINE

1. The N2 subroutine updates all of the ray path solutions that were computed on the preceding pass through the three layer ocean routines. The subroutine then finds the ocean propagation parameters for any new ray paths that may now exist because of a change in target-sonobuoy geometry or ocean conditions from the preceding pass.

2. NRMD

3.
```
        JSR@ .N2
        mnNLP
        mnLPW
        mnNBM
        mnBMS
        BGDAT
    .
    .
    .
.N2:    N2
```

4. NR1 and NR2

5. mnNLP, mnLPW, mnNBM, mnBMS, TSNPW, TSPCW, BOMFG, and ZVAL1

6. mnNLP, mnLPW, mnNBM, mnBMS, CODEW, ZVATA, ZMXAD, ZMNAD, and ZVAL1.

7. See Figure C8.

8. See Listing C8.

9. a. This subroutine provides the code word, starting z value, and the z limits for the NR1 and NR2 Newton-Raphson computation subroutines.

   b. The N2 subroutine operates in the following manner:

      1. All of the solutions in mnLPW are run in the Newton-Raphson computation loop until the solution is updated or found invalid. Solutions that exist both in mnLPW and TSPCW are deleted from TSPCW. If a solution in mnLPW is not also included in TSPCW, it is invalid and deleted.

      2. After all of the solution in mnLPW are examined, the possible ray paths remaining in TSPCW are run in the Newton-Raphson computation loop until a solution is found or until invalidated. All valid solutions are stored in mnLPW so that they can be updated on the next pass through the three layer ocean routines.

      3. Bookkeeping is required in managing the changing solutions in mnLPW. The mnBMS table is used to accomplish this task. Any solution in mnLPW which becomes invalid has its address in mnLPW stored in mnBMS. Any new solutions which are added are placed at addresses in mnLPW which are stored in mnBMS. If no addresses exist in mnBMS, the new solution is added at the end of the mnLPW table. Solutions are deleted from the mnLPW table by zeroing their code words.

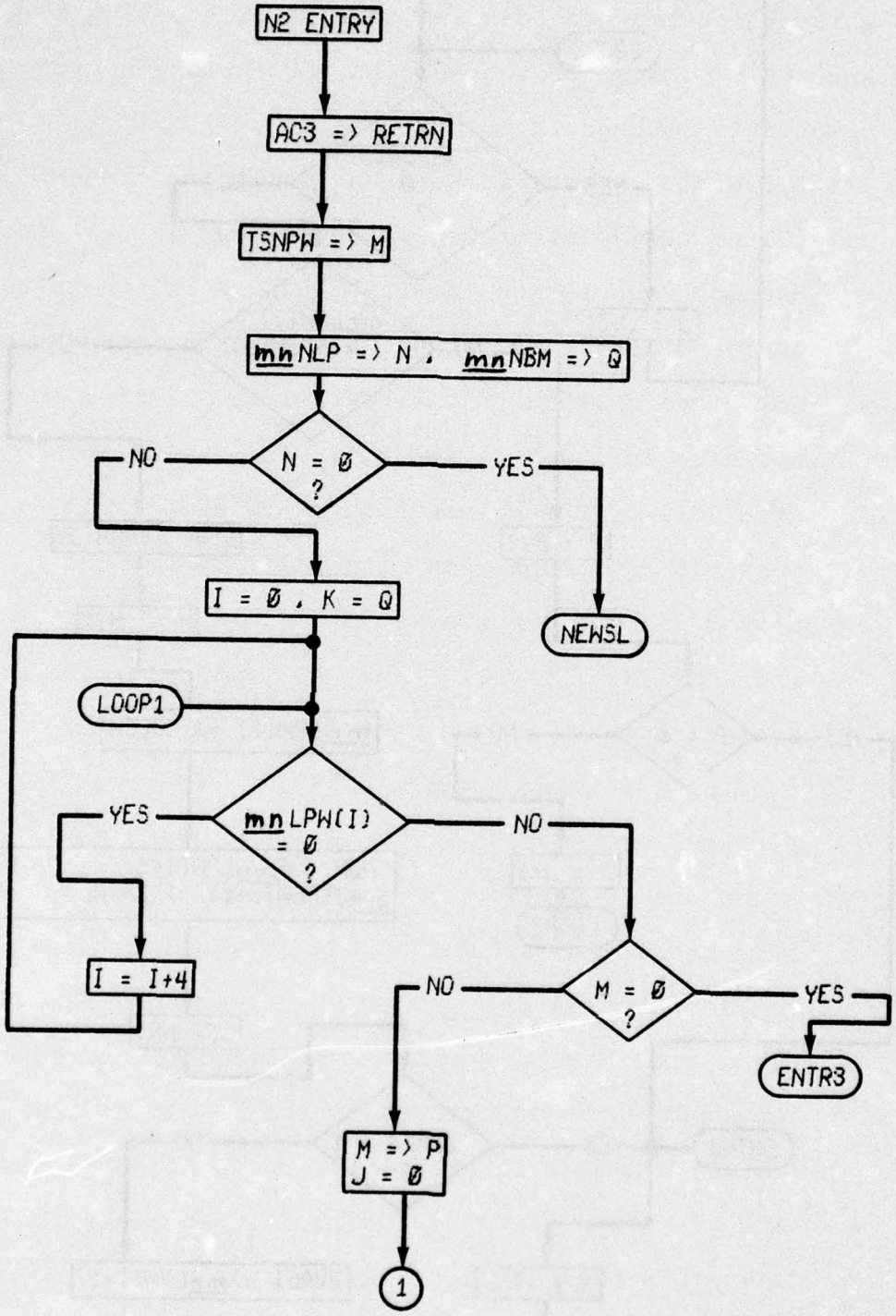

N2 ENTRY
AC3 => RETRN
TSNPW => M
mnNLP => N , mnNBM => Q
N = Ø ?
NO
YES
NEWSL
I = Ø , K = Q
LOOP1
mnLPW(I) = Ø ?
YES
NO
I = I+4
M = Ø ?
NO
YES
ENTR3
M => P
J = Ø
1

FIG. C8

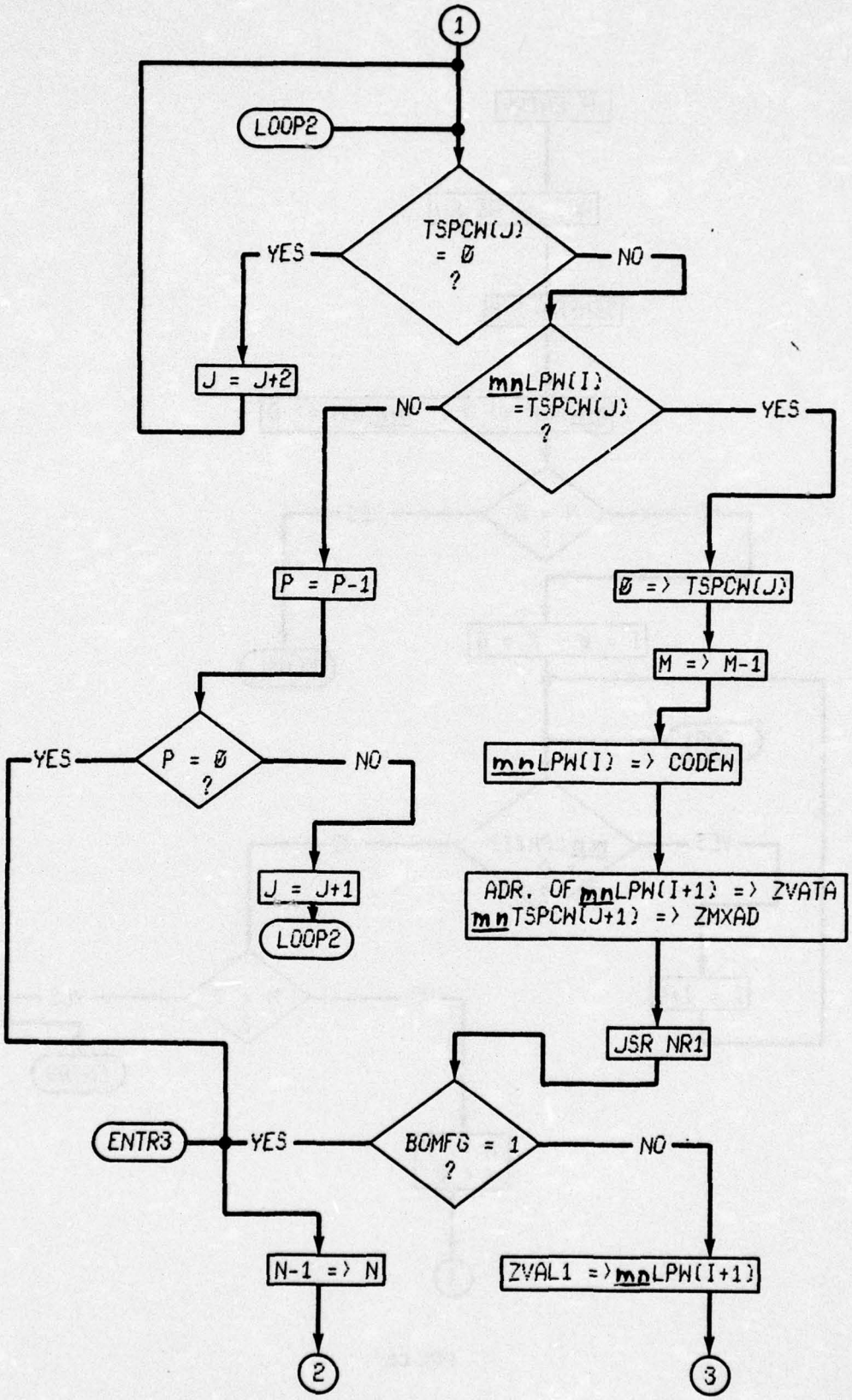


FIG. C8 (CONTINUED)

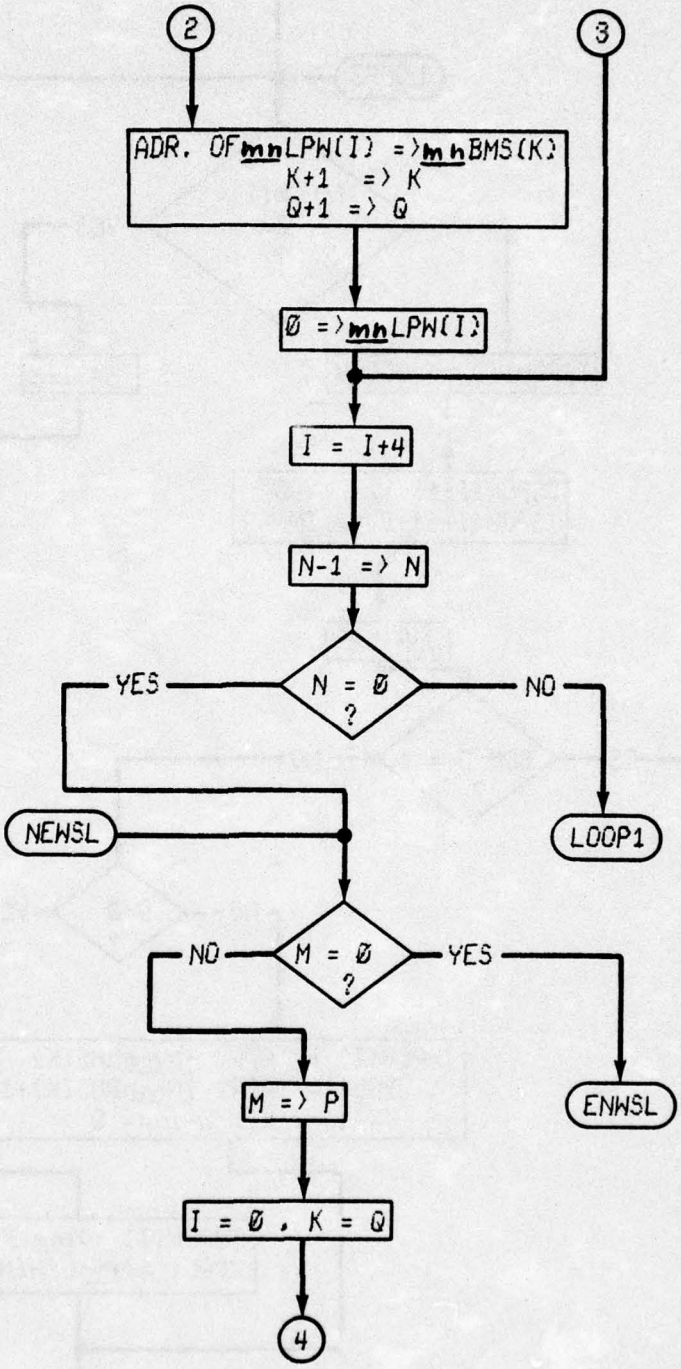


FIG. C8 (CONTINUED)

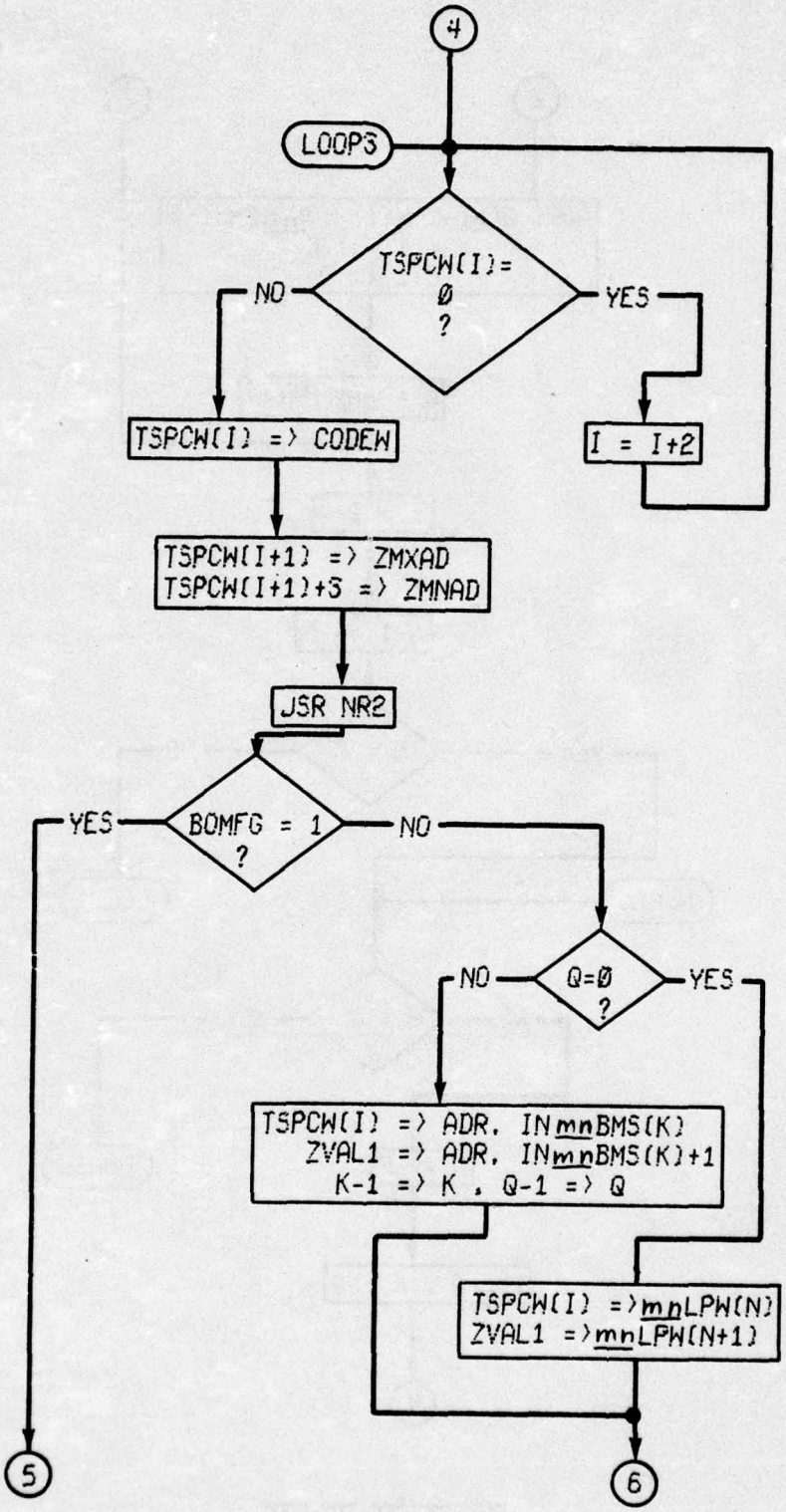


FIG. C8 (CONTINUED)

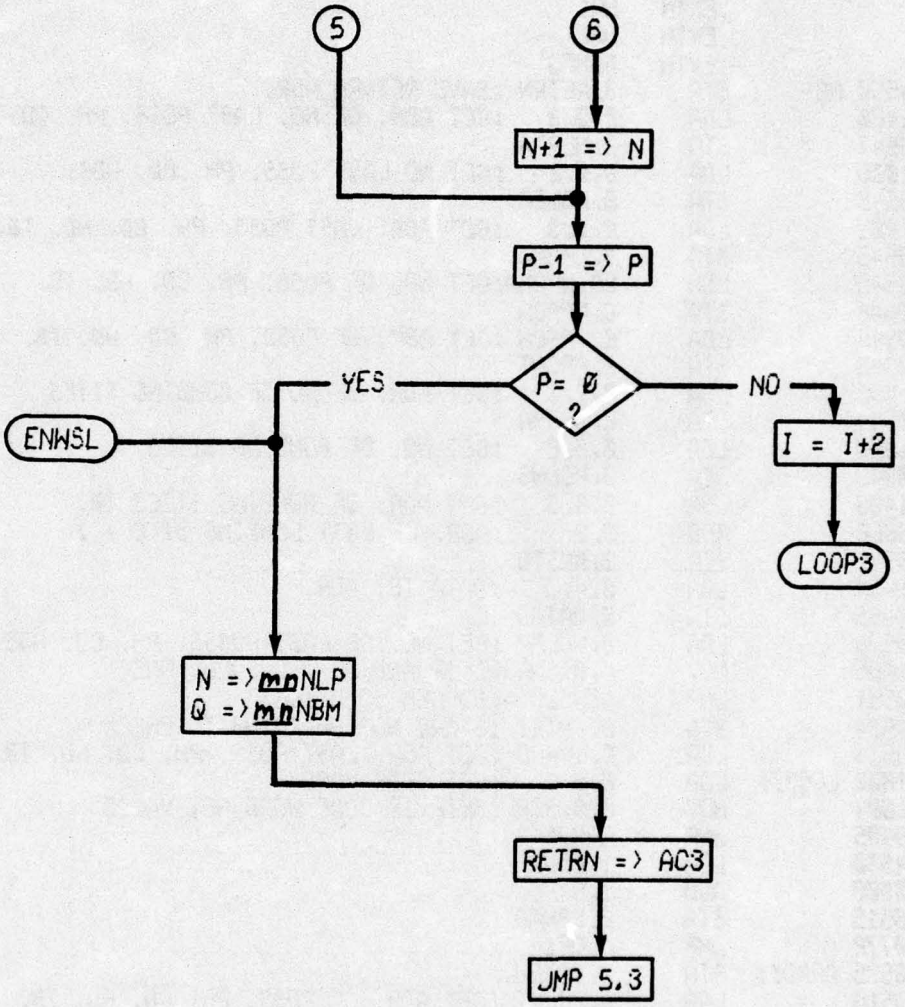


FIG. C8 (CONTINUED)

```
0001  N2

                        .NREL
                        .TITL   N2      ;05/08/74
      000010            .RDX    8
                        .ENT    N2
                        .EXTN   ZVATA
                        .EXTN   ZMXAD
                        .EXTN   ZMNAD
                        .EXTN   TSNPW
                        .EXTN   TSPCW
                        .EXTN   NR1
                        .EXTN   NR2
                        .EXTN   BOMFG
00000'054550 N2:        STA     3,RETRN ;SAVE RETURN ADR.
00001'031400            LDA     2,0,3   ;GET ADR. OF NO. LAST POSS. PH. CD. WDS.
00002'050547            STA     2,NLPPA
00003'021000            LDA     0,0,2   ;GET NO.LAST POSS. PH. CD. WDS.
00004'040546            STA     0,NOLPP
00005'031401            LDA     2,1,3   ;GET ADR. LAST POSS. PH. CD. WD. TB.
00006'050545            STA     2,LPWAD
00007'022545            LDA     @0,NPCWA;GET NO. OF POSS. PH. CD. WD. TB.
00010'040546            STA     0,NPPCW
00011'030544            LDA     2,,PPCW ;GET ADR. OF POSS. PH. CD. WD. TB.
00012'050545            STA     2,PPCWT
00013'031402            LDA     2,2,3   ;GET ADR. OF NO.OF BOMBING SITES
00014'050544            STA     2,NOBMA
00015'021000            LDA     0,0,2   ;GET NO. OF BOMBING SITES
00016'040543            STA     0,NOBMS
00017'031403            LDA     2,3,3   ;GET ADR. OF BOMBING SITES TB.
00020'113000            ADD     0,2     ;ADR. OF LAST BOMBING SITE + 1
00021'050541            STA     2,BMSTB
00022'021404            LDA     0,4,3   ;DATA TB. ADR.
00023'040465            STA     0,DATAD
00024'020526            LDA     0,NOLPP ;GET NO. OF LAST POSSS. PH. CD. WDS.
00025'101005            MOV     0,0,SNR ;SKIP AND DO OLD SOLUTIONS
00026'000551            JMP     NEWSL   ;DO NEW SOLUTIONS
00027'040534            STA     0,CNTR1 ;STORE NO. OF PATHS TO CHECK
00030'030523            LDA     2,LPWAD ;GET ADR. LAST POSS. PH. CD. WD. TB.
00031'021000 LOOP1:     LDA     0,0,2   ;GET CODE WORD
00032'101004            MOV     0,0,SZR ;SKIP IF CODE WORD NOT VALID
00033'000405            JMP     ARND1
00034'024530            LDA     1,FOUR
00035'133000            ADD     1,2
00036'050515            STA     2,LPWAD
00037'000772            JMP     LOOP1
00040'040525 ARND1:     STA     0,CODEW
00041'030516            LDA     2,PPCWT ;GET ADR. OF POSS. PH. CD. WD. TB.
00042'050524            STA     2,PTPPC
00043'020513            LDA     0,NPPCW ;GET NO. OF POSS. PH. CD. WDS.
00044'101005            MOV     0,0,SNR ;SKIP IF NO. IS NON ZERO
00045'000447            JMP     ENTRS   ;DELETE THIS OLD SOLUTION
00046'040521            STA     0,NOPPC
00047'021000 LOOP2:     LDA     0,0,2   ;GET CD. WD. FROM POSS. PH. CD. WDS.
00050'101004            MOV     0,0,SZR
00051'000405            JMP     ARND2
00052'151400            INC     2,2
00053'151400            INC     2,2
00054'050512            STA     2,PTPPC
00055'000772            JMP     LOOP2
```

```
0002  N2
 00056'024507 ARND2:  LDA     1,CODEW ;GET CD. WD. FROM LAST POSS. PH. CD. WDS.
 00057'106415         SUB#    0,1,SNR ;SKIP IF CD. WDS.NOT EQUAL
 00060'000411         JMP     ENTR2   ;OLD AND NEW SOLUTION COINCIDE
 00061'014506         DSZ     NOPPC   ;SKIP IF LAST POSS. PH. CD. WD.
 00062'000402         JMP     .+2     ;FEEP LOOKING
 00063'000431         JMP     ENTR3   ;DELETE THIS OLD SOLUTION
 00064'030502         LDA     2,PTPPC ;GET ADR. OF POSS. PH. CD. WD. TB.
 00065'151400         INC     2,2     ;SET UP NEXT ADR.
 00066'151400         INC     2,2
 00067'050477         STA     2,PTPPC
 00070'000757         JMP     LOOP2   ;GET NEXT POSS. PH. CD.WD.
 00071'102400 ENTR2:  SUB     0,0     ;ZERO IN AC0
 00072'041000         STA     0,0,2   ;ZERO OUT POSS. PH. CD.WD.
 00073'020463         LDA     0,NPPCW ;GET NO. OF POSS. PH. CD. WDS..
 00074'126520         SUBZL   1,1     ;ONE IN AC1
 00075'122400         SUB     1,0     ;SUBTRACT ONE FROM NO.
 00076'040460         STA     0,NPPCW
 00077'035001         LDA     3,1,2   ;GET Z LIMITS ADR. FROM TB.
 00100'056470         STA     @3,NRZMA        ;Z MAX ADR. IN N1AN2
 00101'030452         LDA     2,LPWAD ;GET ADR. OF LAST POSS. PH. CD. WD. TB.
 00102'151400         INC     2,2     ;ADR.OF Z VALUE
 00103'052472         STA     @2,NRZVA;SET UP ADR. IN N1AN2
 00104'020461         LDA     0,CODEW ;CD. WD.
 00105'030403         LDA     2,DATAD ;DATA TB. ADR.
 00106'041022         STA     0,22,2  ;STORE CD. WD. IN DATA TB.
 00107'006463         JSR     @.NR1   ;DO NEWTON RAPHSON LOOP
 00110'000000 DATAD:  0
 00111'022462         LDA     @0,.BMBF;GET BOMB FLAG
 00112'101005         MOV     0,0,SNR ;SKIP IF SOLUTION BOMBED
 00113'000414         JMP     ENTR1   ;STORE NEW Z VALUE
 00114'020436 ENTR3:  LDA     0,NOLPP ;GET NO. OF LAST POSS. PH. CD. WDS.
 00115'126520         SUBZL   1,1     ;ONE IN AC1
 00116'122400         SUB     1,0     ;SUB. ONE FROM NO.
 00117'040433         STA     0,NOLPP
 00120'030433         LDA     2,LPWAD ;GET ADR. LAST POSS. PH. CD. WD. TB.
 00121'052441         STA     @2,BMSTB;STORE ADR. IN BOMBING SITE TB.
 00122'010440         ISZ     BMSTB   ;INCREM. ADR. OF BOMBING SITES
 00123'010436         ISZ     NOBMS   ;INCREM. NO. OF BOMBING SITES
 00124'102400         SUB     0,0
 00125'041000         STA     0,0,2   ;ZERO OUT CODE WORD
 00126'000411         JMP     ENDL1
 00127'034761 ENTR1:  LDA     3,DATAD;ADR OF DATA TABLE
 00130'021423         LDA     0,23,3  ;GET NEW Z VALUE
 00131'025424         LDA     1,24,3
 00132'035425         LDA     3,25,3
 00133'030420         LDA     2,LPWAD ;ADR. OF LAST POSS. CD. WD. TB.
 00134'041001         STA     0,1,2   ;STORE Z VALUE IN TB.
 00135'045002         STA     1,2,2
 00136'055003         STA     3,3,2
 00137'151400 ENDL1:  INC     2,2     ;SETUP NEXT ADR.
 00140'151400         INC     2,2
 00141'151400         INC     2,2
 00142'151400         INC     2,2
 00143'050410         STA     2,LPWAD
 00144'014417         DSZ     CNTR1   ;END OLD SOLUTIONS IF ZERO
 00145'000402         JMP     .+2
 00146'000431         JMP     NEWSL   ;DO NEW SOLUTIONS
 00147'000662         JMP     LOOP1   ;DO NEXT OLD SOLUTION
 00150'000000 RETRN:  0
```

LISTING C8 (Continued)

```
0003  N2
 00151'000000 NLPPA:  0
 00152'000000 NOLPP:  0
 00153'000000 LPWAD:  0
 00154'177777 NPCWA:  TSNPW
 00155'177777 .PPCW:  TSPCW
 00156'000000 NPPCW:  0
 00157'000000 PPCWT:  0
 00160'000000 NOBMA:  0
 00161'000000 NOBMS:  0
 00162'000000 BMSTB:  0
 00163'000000 CNTR1:  0
 00164'000004 FOUR:   4
 00165'000000 CODEW:  0
 00166'000000 PTPPC:  0
 00167'000000 NOPPC:  0
 00170'177777 NRZMA:  ZMXAD
 00171'177777 NRZNA:  ZMNAD
 00172'177777 .NR1:   NR1
 00173'177777 .BMBF:  BOMFG
 00174'177777 .NR2:   NR2
 00175'177777 NRZVA:  ZVATA
 00176'000000 CNTR2:  0
 00177'020757 NEWSL:  LDA     0.NPPCW ;GET NO. OF POSS. PH. CD. WDS. LEFT
 00200'101005         MOV     0.0.SNR ;SKIP IF NON ZERO
 00201'000506         JMP     ENWSL   ;END NEW SOLUTION SEARCH
 00202'040774         STA     0.CNTR2
 00203'020705         LDA     0.DATAD ;DATA TB. ADR.
 00204'040423         STA     0.DTAD1
 00205'030752         LDA     2.PPCWT ;ADR. OF POSS. PH. CD. WD. TB.
 00206'021000 LOOP3:  LDA     0.0.2   ;GET CODE WORD
 00207'040756         STA     0.CODEW
 00210'101004         MOV     0.0.SZR ;SKIP IF CODE WORD ZERO
 00211'000405         JMP     ENTR7   ;CODE WORD O.K.
 00212'151400         INC     2.2     ;SET UP NEXT POSS.PH. CD. WD. TB. ADR.
 00213'151400         INC     2.2
 00214'050743         STA     2.PPCWT
 00215'000771         JMP     LOOP3   ;GET NEXT CODE WORD
 00216'035001 ENTR7:  LDA     3.1.2   ;GET ADR. OF Z LIMITS
 00217'056751         STA     @3.NRZMA;Z MAX. ADR. IN N1AN2
 00220'175400         INC     3.3     ;SET UP Z MIN. ADR.
 00221'175400         INC     3.3
 00222'175400         INC     3.3
 00223'056746         STA     @3.NRZNA;Z MIN. ADR. IN N1AN2
 00224'030403         LDA     2.DTAD1 ;DATA TB. ADR.
 00225'041022         STA     0.22.2  ;STORE CD. WD. IN DATA TB.
 00226'006746         JSR     @.NR2   ;DO NEWTON - RAPHSON LOOPS
 00227'000000 DTAD1:  0
 00230'022743         LDA     @0.,BMBF;GET BOMB FLAG
 00231'101004         MOV     0.0.SZR ;SKIP IF SOLUTION O.K.
 00232'000445         JMP     ENTR4   ;SET UP NEXT CODE WORD
 00233'020726         LDA     0.NOBMS ;GET NO. OF BOMBING SITES
 00234'101005         MOV     0.0.SNR ;SKIP IF BOMBING SITES AVAILABLE
 00235'000422         JMP     ENTR5   ;STORE AT END OF TB.
 00236'030724         LDA     2.BMSTB ;GET ADR. OF BOMBING SITE
 00237'035377         LDA     3.-1.2  ;GET LAST BOMBING SITE ADR.
 00240'020725         LDA     0.CODEW ;GET CODE WORD
 00241'041400         STA     0.0.3   ;STORE IN LAST POSS. PH. CD. WD. TB.
 00242'030765         LDA     2.DTAD1;GET ADR OF DATA TABLE
 00243'021023         LDA     0.23.2  ;GET NEW Z VALUE
```

LISTING C8 (Continued)

```
0004  N2
 00244'041401          STA     0,1,3   ;STORE Z VALUE IN TB.
 00245'021024          LDA     0,24,2
 00246'041402          STA     0,2,3
 00247'021025          LDA     0,25,2
 00250'041403          STA     0,3,3
 00251'014711          DSZ     BMSTB   ;DECREM. ADR. OF BOMBING SITE TB.
 00252'020707          LDA     0,NOBMS ;GET NO. OF BOMBING SITES
 00253'126520          SUBZL   1,1     ;ONE IN AC1
 00254'122400          SUB     1,0     ;SUB. ONE FROM NO.
 00255'040704          STA     0,NOBMS
 00256'000420          JMP     ENTR6   ;FIX NO. OF LAST POSS. PH. CD. WDS.
 00257'034674 ENTR5:   LDA     3,LPWAD ;GET ADR. OF LAST POSS. PH. CD. WD. TB.
 00260'020705          LDA     0,CODEW ;GET CODE WORD
 00261'041400          STA     0,0,3   ;STORE IN TB.
 00262'030745          LDA     2,DTAD1;GET ADR OF DATA TABLE
 00263'021023          LDA     0,23,2  ;GET NEW Z VALUE
 00264'041401          STA     0,1,3   ;STORE Z VALUE IN TB.
 00265'021024          LDA     0,24,2
 00266'041402          STA     0,2,3
 00267'021025          LDA     0,25,2
 00270'041403          STA     0,3,3
 00271'175400          INC     3,3     ;SET UP NEXT ADR.
 00272'175400          INC     3,3
 00273'175400          INC     3,3
 00274'175400          INC     3,3
 00275'054656          STA     3,LPWAD
 00276'010654 ENTR6:   ISZ     NOLPP   ;INCREM. NO. OF LAST POSS. PH. CD. WDS.
 00277'014677 ENTR4:   DSZ     CNTR2   ;SKIP IF ALL PATHS CHECKED
 00300'000402          JMP     .+2     ;SET UP FOR NEXT CODE WORD
 00301'000406          JMP     ENWSL   ;END OF FINDING NEW SOLUTIONS
 00302'030655          LDA     2,PPCWT ;GET ADR. OF POSS. PH. CD. WD. TB.
 00303'151400          INC     2,2     ;SET UP NEXT ADR.
 00304'151400          INC     2,2
 00305'050652          STA     2,PPCWT
 00306'000700          JMP     LOOP3   ;GET NEXT CODE WORD
 00307'020643 ENWSL:   LDA     0,NOLPP ;GET NO. LAST POSS. PATH CD. WDS.
 00310'042641          STA     @0,NLPPA;STORE NO. IN DATA BASE
 00311'020650          LDA     0,NOBMS ;GET NO. OF BOMBING SITES
 00312'042646          STA     @0,NOBMA;STORE NO. IN DATA BASE
 00313'034635          LDA     3,RETRN ;GET RETURN ADR.
 00314'001405          JMP     5,3     ;RETURN
                       .END
```

LISTING C8 (Continued)

N3 SUBROUTINE

1. The N3 subroutine transfers the final ray path ocean propagation parameters to the proper target-sonobuoy basic solution table.

2. NRMD

3.
```
          JSR@ .N3
          m1NBS
          m1BST
     .
     .
     .
.N3       N3
```

4. NONE

5. TSNIB and TSIBS

6. m1NBS and m1BST

7. See Figure C9.

8. See Listing C9.

9. The contents of TSNIB and TSIBS are transferred into m1NBS and m1BST respectively.

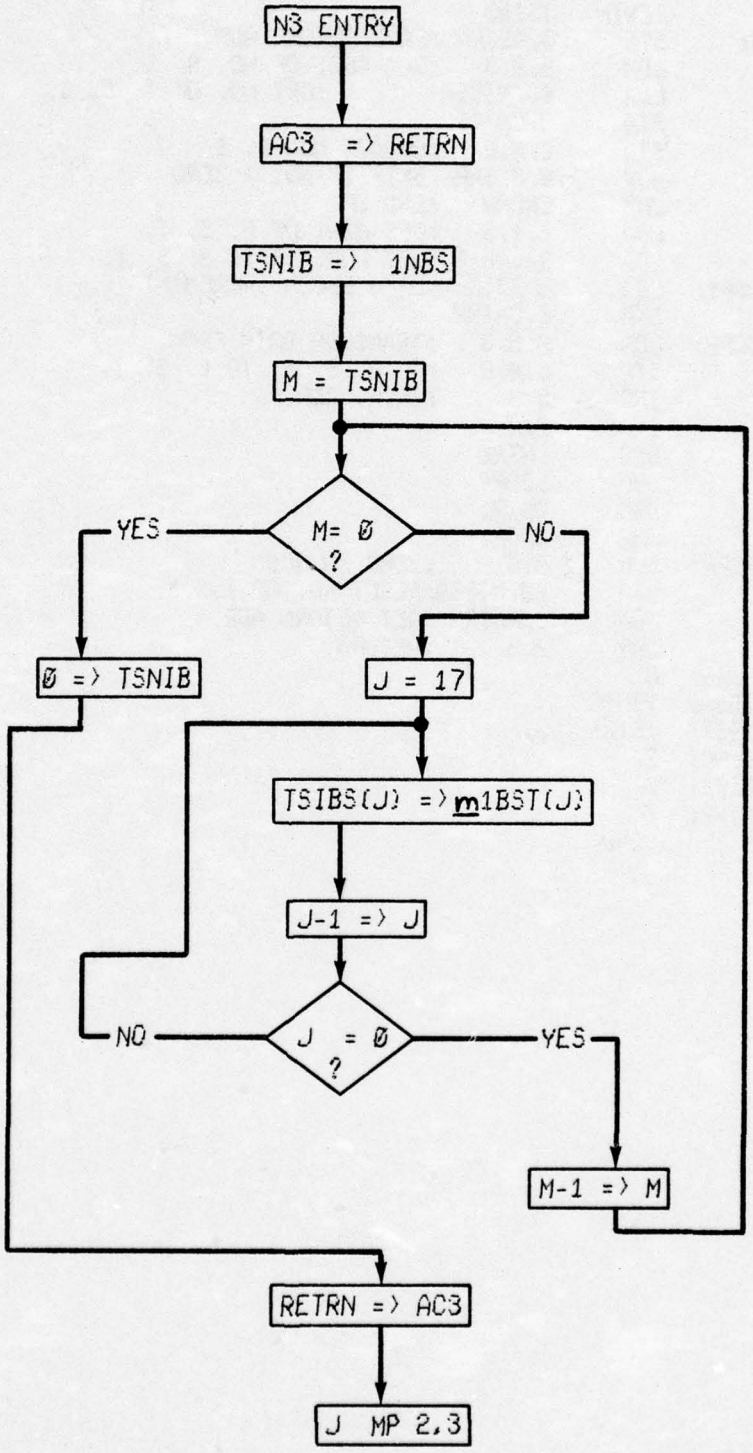

N3 ENTRY
AC3 => RETRN
TSNIB => 1NBS
M = TSNIB
M= Ø ?
YES
NO
Ø => TSNIB
J = 17
TSIBS(J) => m1BST(J)
J-1 => J
J = Ø ?
NO
YES
M-1 => M
RETRN => AC3
J MP 2,3

FIG. C9

```
                        .NREL
                        .TITL   N3      ;03/13/74
        000010          .RDX    8
                        .ENT    N3
                        .EXTN   TSNIB
                        .EXTN   TSIBS
00000'054427 N3:        STA     3,RETRN ;SAVE RETURN ADR.
00001'031400            LDA     2,0,3   ;GET ADR. OF NO. B. S.
00002'022426            LDA     @0,NIBSA        ;GET NO. OF I. B. S.
00003'040430            STA     0,CNTR1
00004'041000            STA     0,0,2   ;UPDATE NO. B. S.
00005'101005            MOV     0,0,SNR ;SKIP IF NO. > ZERO
00006'000415            JMP     ENDRR   ;END UP
00007'031401            LDA     2,1,3   ;GET ADR. OF B. S. T.
00010'034421            LDA     3,.IBST ;GET ADR. OF I. B. S. T.
00011'020421 LOOP1:     LDA     0,BSINC ;DATA BLOCK INCREMENT
00012'040422            STA     0,CNTR2
00013'021400 LOOP2:     LDA     0,0,3   ;TRANSFER DATA FROM
00014'041000            STA     0,0,2   ;I. B. S. T. TO B. S. T.
00015'175400            INC     3,3     ;INCR. ADR.'S
00016'151400            INC     2,2
00017'014415            DSZ     CNTR2
00020'000773            JMP     LOOP2
00021'014412            DSZ     CNTR1
00022'000767            JMP     LOOP1
00023'102400 ENDRR:     SUB     0,0     ;ZERO IN AC0
00024'042404            STA     @0,NIBSA;RESET NO. OF I,B,S.
00025'034402            LDA     3,RETRN ;GET RETURN ADR.
00026'001402            JMP     2,3     ;RETURN
00027'000000 RETRN:     0
00030'177777 NIBSA:     TSNIB
00031'177777 .IBST:     TSIBS
00032'000021 BSINC:     21
00033'000000 CNTR1:     0
00034'000000 CNTR2:     0
                        .END
```

NR1A2 (NR1 and NR2) SUBROUTINE

1. The NR1A2 subroutine has two entry points which are used by the N2 subroutine. NR1 is used to run a Newton-Raphson calculation to update a solution from the mnLPW table. NR2 is used to run a Newton-Raphson calculation on a possible ray path from the TSPCW table.

2. N2

3.
```
          JSR@ .NR1
          BGDAT
     .
     .
     .
.NR1:     NR1
          JSR@ .NR2
          BGDAT
      .
      .
      .
.NR2:     NR2
```

4. FPMP, NRLA, NRLB, NRMB, CPGN, DSPP, and SORT.

5. ZVAL1, BGDAT TABLE, BBMXF, BMBFG, FUDGE, DVBBF, ZVATA, ZMXAD, and ZMNAD.

6. BOMFG, ZVAL1, ZMAX1, and FDV1.

7. See Figure C10.

8. See Listing C10.

9. a) NR1 will run a maximum of 8 Newton-Raphson loops.

   b) NR2 will run a maximum of 64 Newton-Raphson loops.

   c) The maximum number of Newton-Raphson loops will not be run if the calculated horizontal range after a loop is within $\pm$ one eighth of a meter from the actual horizontal range.

   d) NR1 is run with solutions that existed on the preceding pass and usually requires one or two loops to satisfy the $\pm$1/8 meter criteria.

   e) NR2 is run with ray paths that are new and do not have a z value which may be close to the correct value if it exists. NR2 starts with a z value equal to the z maximum limit. If the solution fails then the path is run again starting with a z value equal to the z minimum limit + a delta value. The exact value of the z minimum limit cannot be used because it results in infinite ray path gains.

   f) If a solutions becomes invalid or does not exist, then the BOMFG is set to a one which signals the N2 subroutine to delete the solution.

   g) The DVCR subroutine which is part of NR1A2 alters the value of TDV1 so that it never approach a zero value. A zero value for TDV1 results in an infinite gain for the ray path. This is an error inherent in classical ray trace programs and is referred to as a false caustic. The TDV1 value is altered by adding a portion of the TDV1 value calculated at the z maximum limit

value of the propagation mode. TDV1 values for direct paths (NUMCY = -1) and all 0-4 mode ray paths are not altered because they never equal zero.

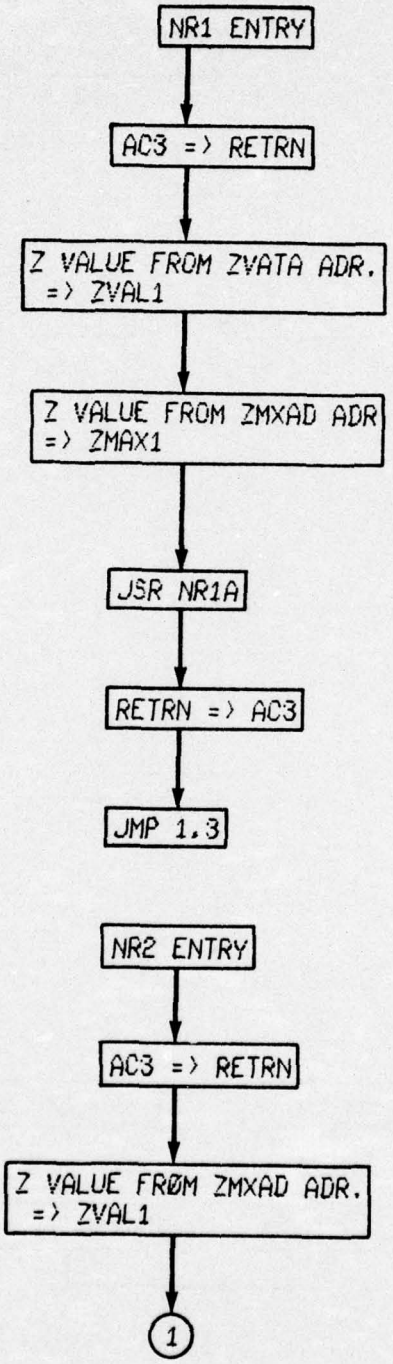

NR1 ENTRY
AC3 => RETRN
Z VALUE FROM ZVATA ADR.
=> ZVAL1
Z VALUE FROM ZMXAD ADR
=> ZMAX1
JSR NR1A
RETRN => AC3
JMP 1,3
NR2 ENTRY
AC3 => RETRN
Z VALUE FRØM ZMXAD ADR.
=> ZVAL1
1

FIG. C10

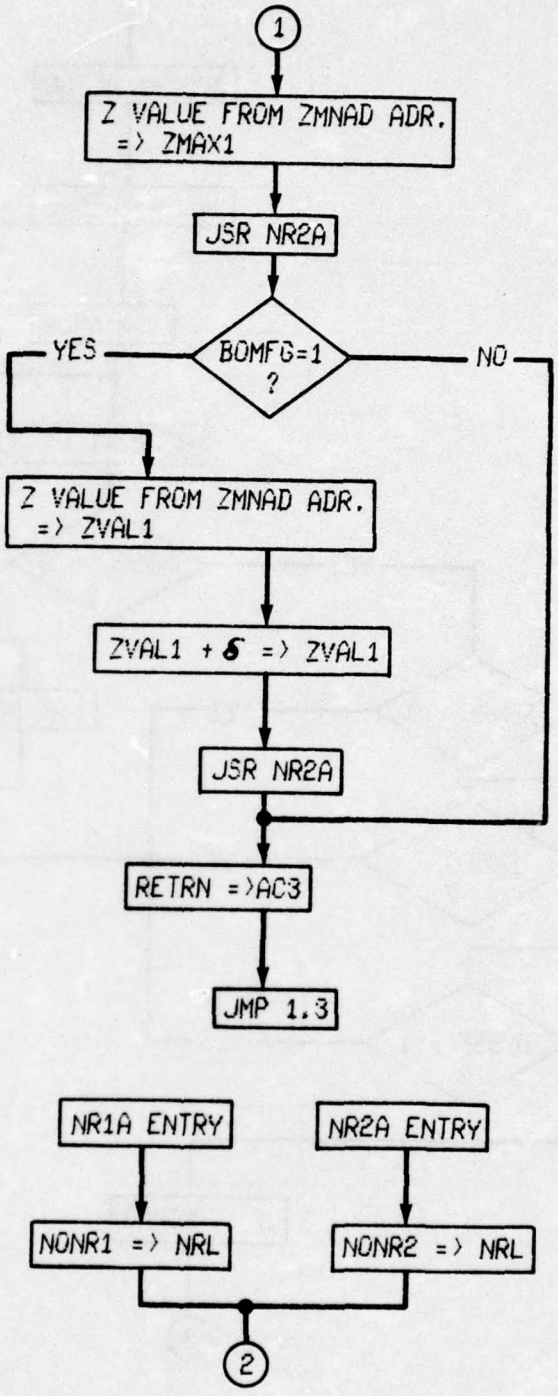


FIG. C10 (CONTINUED)

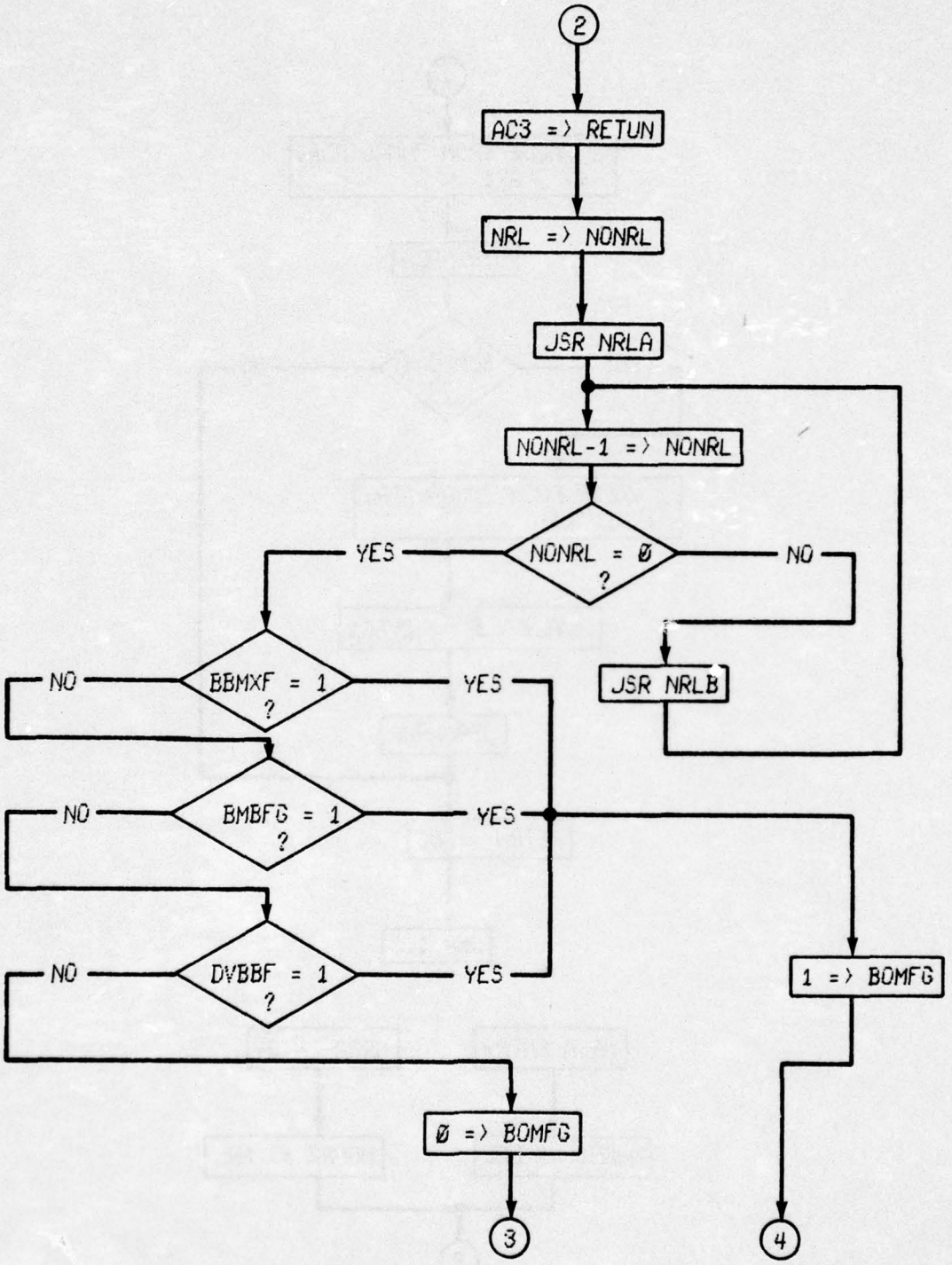


FIG. C10 (CONTINUED)

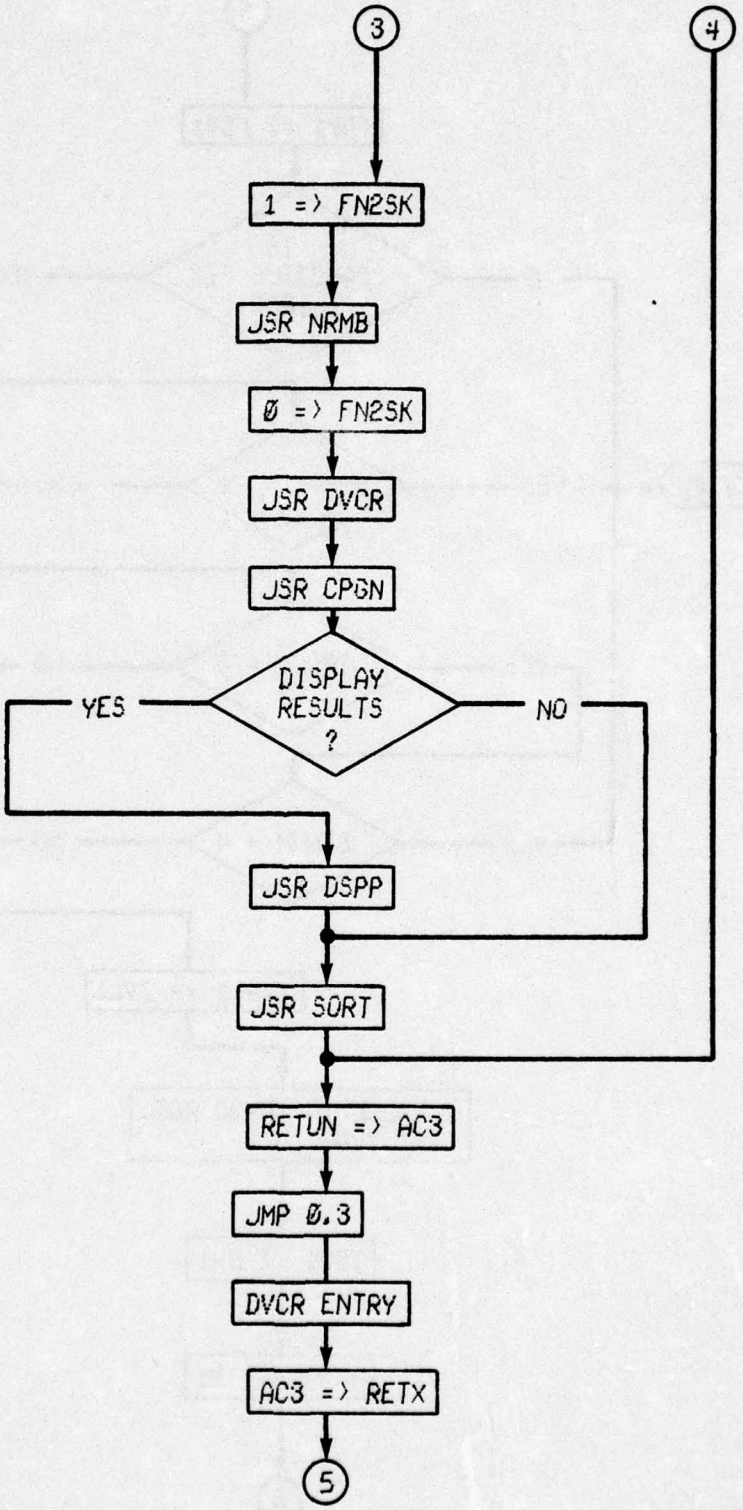


FIG. C10 (CONTINUED)

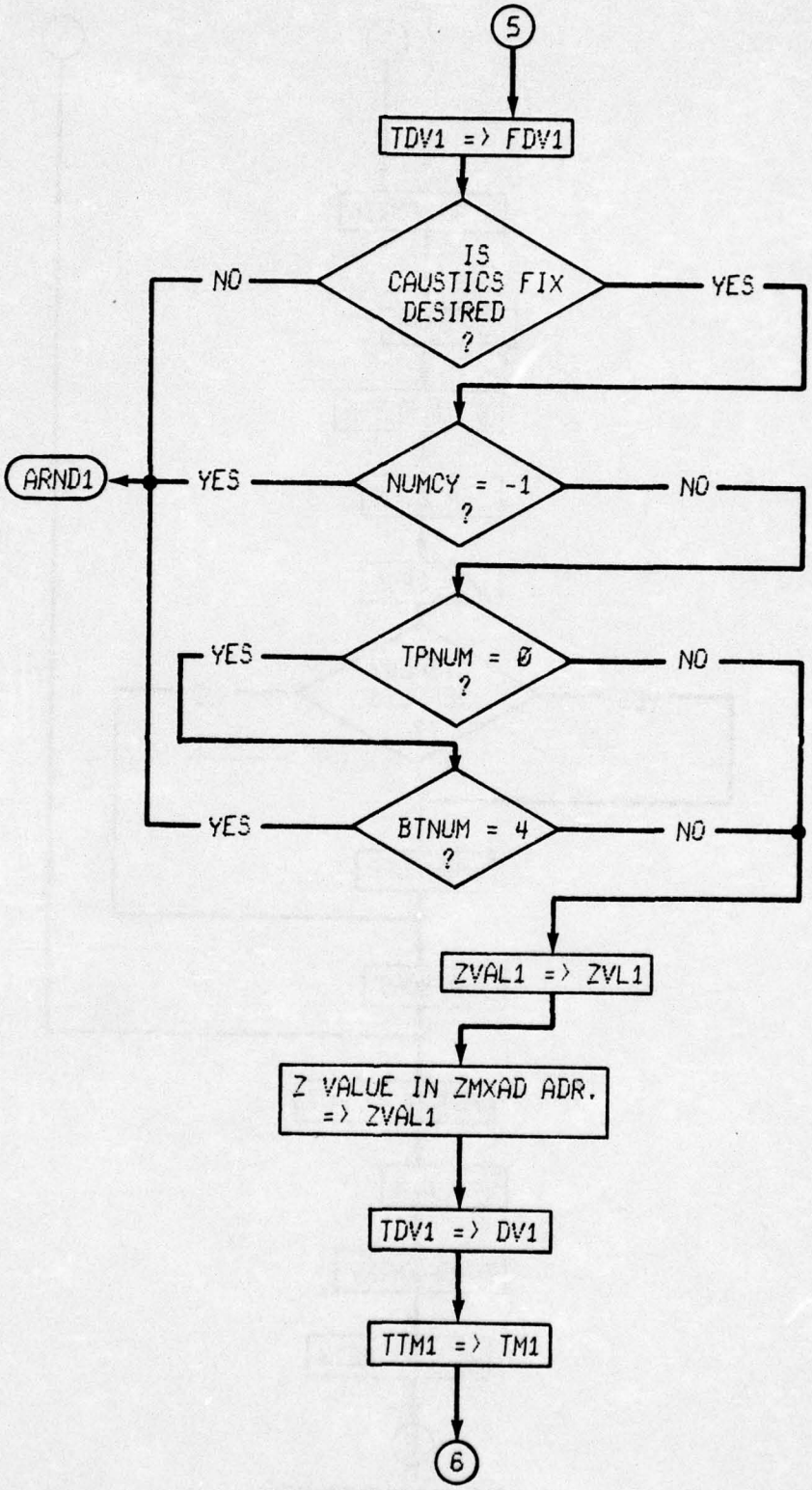


FIG. C10 (CONTINUED)

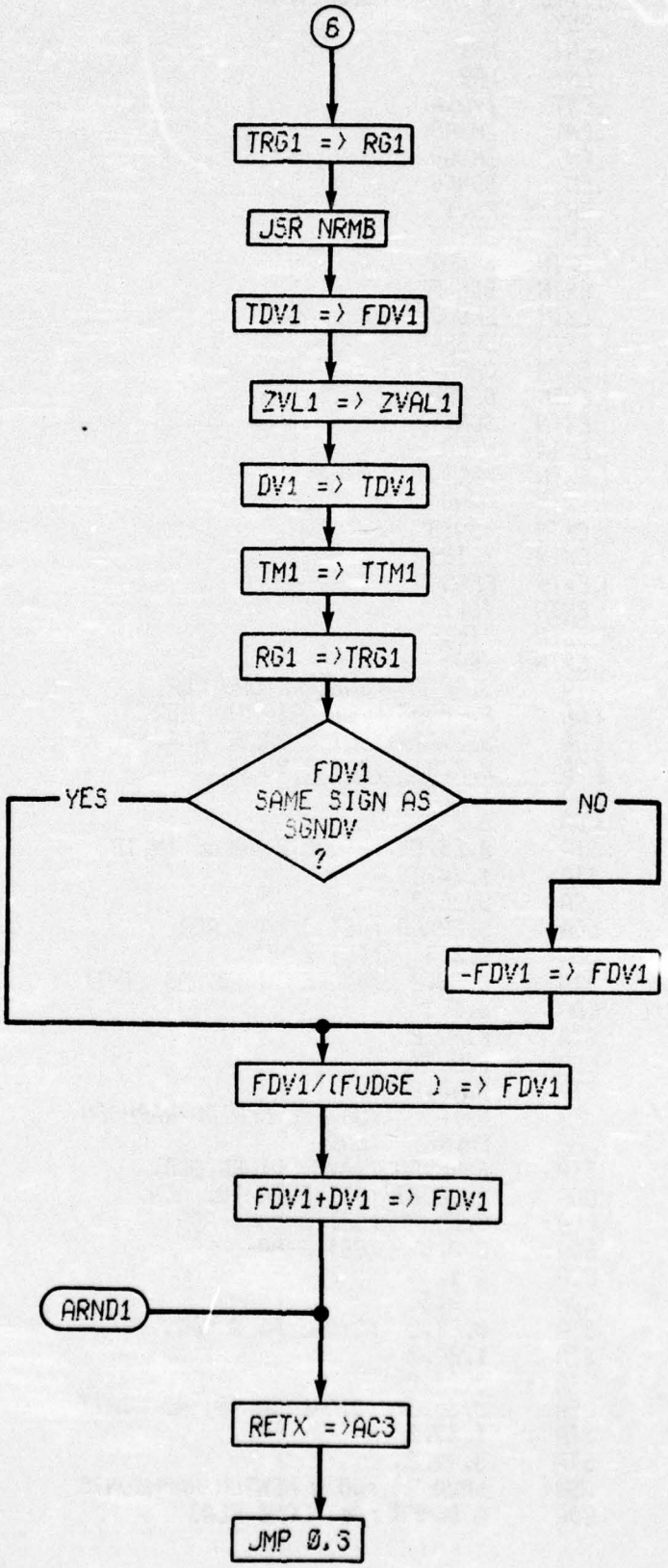


FIG. C10 (CONTINUED)

```
                    .NREL
                    .TITL   NR1A2   ;010/17/74
          000010    .RDX    8
                    .ENT    NR1
                    .ENT    NR2
                    .ENT    ZVATA
                    .ENT    ZMXAD
                    .ENT    ZMNAD
                    .ENT    BOMFG
                    .ENT    FDV1
                    .ENT    SKFDT
                    .EXTN   BGDAT
                    .EXTN   BBMXF
                    .EXTN   BMBFG
                    .EXTN   DVBBF
                    .EXTN   CPGN
                    .EXTN   DSPRP
                    .EXTN   SORT
                    .EXTN   NRLA
                    .EXTN   NRLB
                    .EXTN   NRMB
                    .EXTN   TSNIB
                    .EXTN   TSIBS
                    .EXTN   FFAD
                    .EXTN   TDV1
                    .EXTN   TTM1
                    .EXTN   TRG1
00000'054463 NR1:   STA     3,RETRN ;SAVE RETURN ADR.
00001'030463        LDA     2,.BGDT ;GET DATA TB. ADR.
00002'034463        LDA     3,ZVATA ;GET Z VALUE ADR.
00003'021400        LDA     0,0,3   ;GET Z VALUE
00004'025401        LDA     1,1,3
00005'035402        LDA     3,2,3
00006'041023        STA     0,23,2  ;STORE Z VALUE IN TB.
00007'045024        STA     1,24,2
00010'055025        STA     3,25,2
00011'034532        LDA     3,ZMXAD ;GET Z MAX. ADR.
00012'021400        LDA     0,0,3   ;GET Z MAX.
00013'041036        STA     0,36,2  ;STORE IN TB. AS LIMIT
00014'021401        LDA     0,1,3
00015'041037        STA     0,37,2
00016'021402        LDA     0,2,3
00017'041040        STA     0,40,2
00020'004450        JSR     NR1A    ;DO ONE NEWTON-RAPHSON
00021'000434        JMP     ENDRR   ;END
00022'054441 NR2:   STA     3,RETRN ;SAVE RETURN ADR.
00023'030441        LDA     2,.BGDT ;GET DATA TB. ADR.
00024'034517        LDA     3,ZMXAD ;GET Z MAX. ADR.
00025'021400        LDA     0,0,3   ;GET Z MAX.
00026'025401        LDA     1,1,3
00027'035402        LDA     3,2,3
00030'041023        STA     0,23,2  ;STORE AS Z VAL.
00031'045024        STA     1,24,2
00032'055025        STA     3,25,2
00033'041036        STA     0,36,2  ;STORE IN TB. AS LIMIT
00034'045037        STA     1,37,2
00035'055040        STA     3,40,2
00036'004434        JSR     NR2A    ;DO N NEWTON-RAPHSON7S
00037'020430        LDA     0,BOMFG ;GET BOMB FLAG
```

```
 00040'101005          MOV     0.0.SNR ;SKIP IF BOMBED
 00041'000414          JMP     ENDRR   ;END
 00042'030422          LDA     2..BGDT ;GET DATA TB. ADR.
 00043'034423          LDA     3.ZMNAD ;GET Z MIN. ADR.
 00044'020413          LDA     0.INCR1
 00045'113000          ADD     0.2
 00046'050405          STA     2.DATA1
 00047'054402          STA     3.ZAD1
 00050'006517          JSR     @.FADD
 00051'000000 ZAD1:    0
 00052'000060'         FGAD1
 00053'000000 DATA1:   0
 00054'004416          JSR     NR2A    ;DO N NEWTON-RAPHSON'S
 00055'034406 ENDRR:   LDA     3.RETRN ;GET RETURN ADR.
 00056'001401          JMP     1.3     ;RETURN
 00057'000023 INCR1:   23
 00060'037762 FGAD1:   037762
 00061'077777          077777
 00062'177777          177777
 00063'000000 RETRN:   0
 00064'177777 .BGDT:   BGDAT
 00065'000000 ZVATA:   0
 00066'000000 ZMNAD:   0
 00067'000000 BOMFG:   0
 00070'020463 NR1A:    LDA     0.NONR1 ;GET NO. OF N-R LOOPS
   00071'000402          JMP     ENTR1
 00072'020462 NR2A:    LDA     0.NONR2 ;GET NO. OF N-R LOOPS
 00073'054462 ENTR1:   STA     3.RETUN ;SAVE RETURN ADR.
 00074'030770          LDA     2..BGDT ;GET DATA TB. ADR.
 00075'041035          STA     0.35.2  ;STORE NO. IN TB.
 00076'006460          JSR     @.NRLA  ;DO NEWTOM-RAPHSON
 00077'000064'         BGDAT
 00100'030764 LOOP1:   LDA     2..BGDT ;GET DATA TB. ADR.
 00101'021035          LDA     0.35.2  ;GET NO. OF LOOPS
 00102'126520          SUBZL   1.1     ;ONE IN AC1
 00103'122400          SUB     1.0     ;NO-ONE
 00104'041035          STA     0.35.2  ;STORE NO. IN TB.
 00105'101004          MOV     0.0.SZR ;SKIP IF NO. ZERO
 00106'000441          JMP     ENTR2   ;DO NEXT N-R
 00107'022451          LDA     @0..BBMX        ;GET BOMB FLAG
 00110'026451          LDA     @1..BBMN
 00111'032451          LDA     @2..BBDV
 00112'176400          SUB     3.3     ;ZERO IN AC3
 00113'107000          ADD     0.1
 00114'133004          ADD     1.2.SZR ;SKIP IF NO BOMBING
 00115'175400          INC     3.3     ;ONE IN AC3
 00116'054751          STA     3.BOMFG ;STORE IN BOMB FLAG
 00117'175004          MOV     3.3.SZR ;SKIP IF NO BOMBING
 00120'000424          JMP     ENTR3   ;END
 00121'102520          SUBZL   0.0
 00122'030742          LDA     2..BGDT
 00123'041034          STA     0.34.2
 00124'006442          JSR     @.NRMB
 00125'000077'         BGDAT
 00126'102400          SUB     0.0
 00127'030735          LDA     2..BGDT
 00130'041034          STA     0.34.2
 00131'004437          JSR     DVCR
 00132'006431          JSR     @.CPGN  ;COMPUTE GAIN. ETC.
```

LISTING C10 (Continued)

```
00133'000125'          BGDAT
00134'000403           JMP     .+3       ;SKIP OVER DISPLAY
00135'006427           JSR     @.DSPP    ;DISPLAY RESULTS
00136'000133'          BGDAT
00137'006426           JSR     @.SORT    ;SORT BY GAINS
00140'000136'          BGDAT
00141'177777           TSNIB
00142'177777           TSIBS
00143'000000 ZMXAD:    0
00144'101000 ENTR3:    MOV     0,0       ;       JSR     3       ;INTERRUPT
00145'034410           LDA     3,RETUN   ;GET RETURN ADR.
00146'001400           JMP     0,3       ;RETURN
00147'101000 ENTR2:    MOV     0,0       ;       JSR     3       ;INTERRUPT
00150'006407           JSR     @.NRLB    ;DO NEWTON-RAPHSON
00151'000140'          BGDAT
00152'000726           JMP     LOOP1     ;LOOP AGAIN
00153'000010 NONR1:    10
00154'000100 NONR2:    100
00155'000000 RETUN:    0
00156'177777 .NRLA:    NRLA
00157'177777 .NRLB:    NRLB
00160'177777 .BBMX:    BBMXF
00161'177777 .BBMN:    BMBFG
00162'177777 .BBDV:    DVBBF
00163'177777 .CPGN:    CPGN
00164'177777 .DSPP:    DSPRP
00165'177777 .SORT:    SORT
00166'177777 .NRMB:    NRMB
00167'177777 .FADD:    FFAD
00170'054562 DVCR:     STA     3,RETX
00171'030673           LDA     2,.BGDT
00172'034561           LDA     3,.TDV1
00173'021400           LDA     0,0,3
00174'040562           STA     0,FDV1
00175'021401           LDA     0,1,3
00176'040561           STA     0,FDV2
00177'021402           LDA     0,2,3
00200'040560           STA     0,FDV3
00201'000547 SKFDT:    JMP     ARND1
00202'021032           LDA     0,32,2    ;NO. OF HF. CYC.
00203'101112           MOVL#   0,0,SZC   ;SKIP IF NOT - 1
00204'000544           JMP     ARND1     ;SKIP FAKE DERIV.
00205'021026           LDA     0,26,2    ;TOP LY. NO.
00206'101004           MOV     0,0,SZR
00207'000405           JMP     ARND2     ;DO FAKE DERIV.
00210'021027           LDA     0,27,2    ;BOT. LY. NO.
00211'101220           MOVZR   0,0
00212'101224           MOVZR   0,0,SZR   ;SKIP IF NOT 0-4
00213'000535           JMP     ARND1     ;SKIP FAKE DERIV.
00214'021023 ARND2:    LDA     0,23,2
00215'040544           STA     0,ZVL1
00216'021024           LDA     0,24,2
00217'040543           STA     0,ZVL2
00220'021025           LDA     0,25,2
00221'040542           STA     0,ZVL3
00222'034721           LDA     3,ZMXAD   ;Z MAX. ADR.
00223'021400           LDA     0,0,3
00224'041023           STA     0,23,2
00225'021401           LDA     0,1,3
```

LISTING C10 (Continued)

```
00226'041024          STA     0.24,2
00227'021402          LDA     0,2,3
00230'041025          STA     0.25,2
00231'034522          LDA     3,.TDV1
00232'021400          LDA     0,0,3
00233'040531          STA     0.DV1
00234'021401          LDA     0,1,3
00235'040530          STA     0.DV2
00236'021402          LDA     0,2,3
00237'040527          STA     0.DV3
00240'034514          LDA     3,.TTM1
00241'021400          LDA     0,0,3
00242'040525          STA     0.TM1
00243'021401          LDA     0,1,3
00244'040524          STA     0.TM2
00245'021402          LDA     0,2,3
00246'040523          STA     0.TM3
00247'034506          LDA     3,.TRG1
00250'021400          LDA     0,0,3
00251'040521          STA     0.RG1
00252'021401          LDA     0,1,3
00253'040520          STA     0.RG2
00254'021402          LDA     0,2,3
00255'040517          STA     0.RG3
00256'006710          JSR@    .NRMB
00257'000151'.BGDA:   BGDAT
00260'034473          LDA     3,.TDV1
00261'021400          LDA     0,0,3
00262'040474          STA     0.FDV1
00263'021401          LDA     0,1,3
00264'040473          STA     0.FDV2
00265'021402          LDA     0,2,3
00266'040472          STA     0.FDV3
00267'030770          LDA     2,.BGDA ;RESTORE ACT. Z
00270'020471          LDA     0.ZVL1
00271'041023          STA     0.23,2
00272'020470          LDA     0.ZVL2
00273'041024          STA     0.24,2
00274'020467          LDA     0.ZVL3
00275'041025          STA     0.25,2
00276'034455          LDA     3,.TDV1 ;RESTORE ACT. DV.
00277'020465          LDA     0.DV1
00300'041400          STA     0,0,3
00301'020464          LDA     0.DV2
00302'041401          STA     0,1,3
00303'020463          LDA     0.DV3
00304'041402          STA     0,2,3
00305'034447          LDA     3,.TTM1
00306'020461          LDA     0.TM1
00307'041400          STA     0,0,3
00310'020460          LDA     0.TM2
00311'041401          STA     0,1,3
00312'020457          LDA     0.TM3
00313'041402          STA     0,2,3
00314'034441          LDA     3,.TRG1
00315'020455          LDA     0.RG1
00316'041400          STA     0,0,3
00317'020454          LDA     0.RG2
00320'041401          STA     0,1,3
```

LISTING C10 (Continued)

```
0005  NR1A2                                  NSWC/WOL/TR 75-115
  00321'020453            LDA     0,RG3
  00322'041402            STA     0,2,3
  00323'020434            LDA     0,FDV2
  00324'025051            LDA     1,51,2
  00325'176620            SUBZR   3,3
  00326'117400            AND     0,3
  00327'137000            ADD     1,3
  00330'175133            MOVZL#  3,3,SNC
  00331'000407            JMP     ARND3
  00332'024426            LDA     1,FDV3
  00333'124405            NEG     1,1,SNR
  00334'100401            NEG     0,0,SKP
  00335'100000            COM     0,0
  00336'040421            STA     0,FDV2
  00337'044421            STA     1,FDV3
  00340'020416 ARND3:     LDA     0,FDV1
  00341'024434            LDA     1,FUDGE
  00342'122400            SUB     1,0
  00343'040413            STA     0,FDV1
  00344'006623            JSRe    .FADD
  00345'000356'           FDV1
  00346'000364'           DV1
  00347'000356'           FDV1
  00350'034402 ARND1:     LDA     3,RETX
  00351'001400            JMP     0,3
  00352'000000 RETX:      0
  00353'177777 .TDV1:     TDV1
  00354'177777 .TTM1:     TTM1
  00355'177777 .TRG1:     TRG1
  00356'000000 FDV1:      0
  00357'000000 FDV2:      0
  00360'000000 FDV3:      0
  00361'000000 ZVL1:      0
  00362'000000 ZVL2:      0
  00363'000000 ZVL3:      0
  00364'000000 DV1:       0
  00365'000000 DV2:       0
  00366'000000 DV3:       0
  00367'000000 TM1:       0
  00370'000000 TM2:       0
  00371'000000 TM3:       0
  00372'000000 RG1:       0
  00373'000000 RG2:       0
  00374'000000 RG3:       0
  00375'000000 FUDGE:     0
                          .END
```

LISTING C10 (Continued)

NRLAB (NRLA AND NRLB) SUBROUTINE

1. The NRLAB subroutine has two entry points which are used by the NR1A2 subroutine. NRLA is entered on the first Newton-Raphson calculation loop for each ray path. NRLB is entered for all the rest of the loops. This subroutine checks to see if preceding solutions are still valid and if new ray paths now exist. It also calculates the next z value to use for the Newton-Raphson calculation loop.

2. NR1A2

3.
```
          JSR@ .NRLA
          BGDAT
     .
     .
     .
.NRLA:    NRLA
          JSR@ .NRLB
          BGDAT
     .
     .
     .
.NRLB:    NRLB
```

4. FPMP and NRMA
5. TDV1, TRG1, ZVAL1, DLRG1, ZMAX1, and BMBFG
6. ZVAL1, BBMXF, and DVBBF
7. See Figure C11.
8. See Listing C11.
9. a) The Newton-Raphson calculation is run until one of the following conditions is met:
   1. The number of loops equals NONRL.
   2. The calculated value of horizontal range, TRG1, is within $\pm$ DLRG1 of the actual horizontal range A1HR.
   3. One of the bomb flags BBMXF, DVBBF, or BMBFG equals one.

   b) The Newton-Raphson calculation computes a new value of z which equals

$$z_{NEW} = z_{OLD} + \left(\frac{A1HR - TRG1}{TDV1}\right)$$

   The new value is then used in another Newton-Raphson calculation which moves the value of TRG1 closer to A1HR. TDV1 is always used in the calculation instead of FDV1.

   c) If the value of ż exceeds the z maximum limit the solution is invalid and BBMXF is set to one. If the sign of TDV1 changes then the solution is also invalid and DVBBF is set to one.

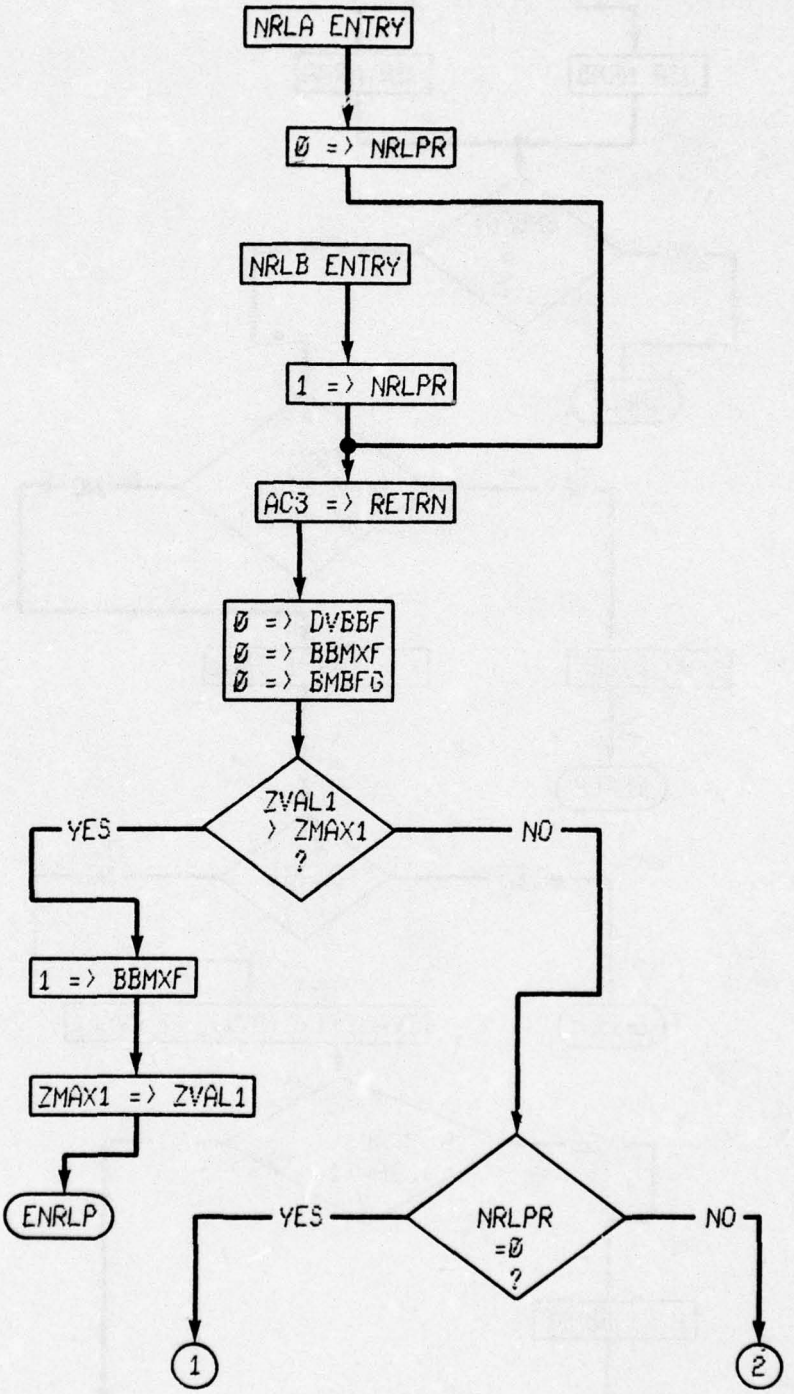

NRLA ENTRY
Ø => NRLPR
NRLB ENTRY
1 => NRLPR
AC3 => RETRN
Ø => DVBBF
Ø => BBMXF
Ø => BMBFG
ZVAL1 > ZMAX1 ?
YES
NO
1 => BBMXF
ZMAX1 => ZVAL1
ENRLP
NRLPR =Ø ?
YES
NO
1
2

FIG. C11

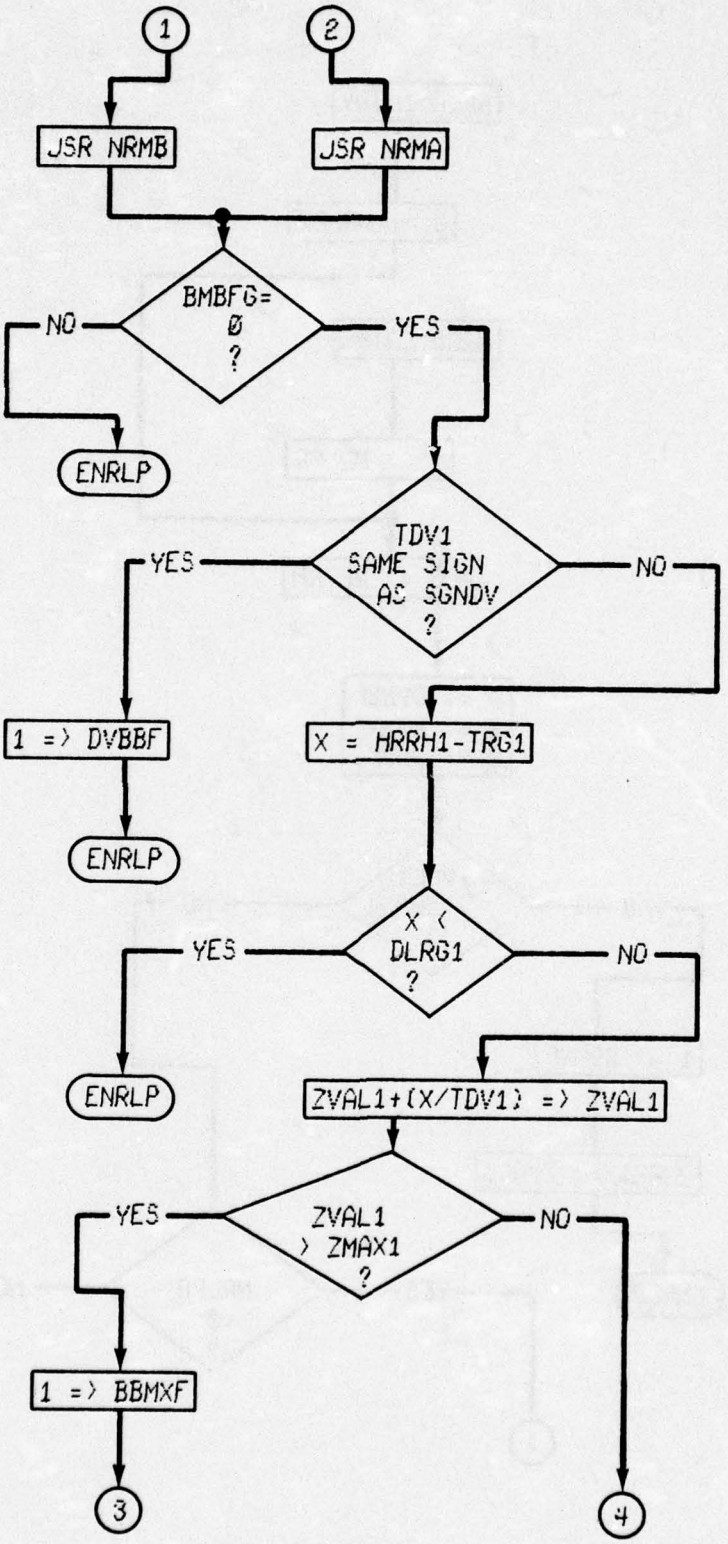


FIG. C11 (CONTINUED)

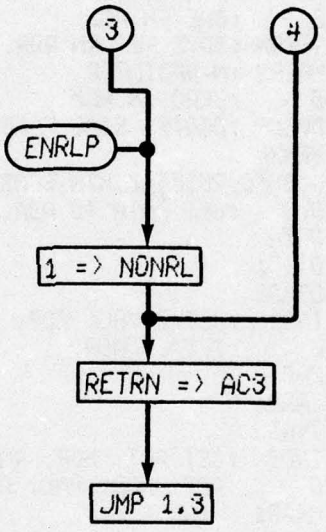


FIG. C11 (CONTINUED)

```
0001  NRLAB

                        .NREL
                        .TITL   NRLAB   ;05/06/74
        000010          .RDX    8
                        .ENT    NRLA
                        .ENT    NRLB
                        .ENT    BBMXF
                        .ENT    DVBBF
                        .EXTN   NRMA
                        .EXTN   NRMB
                        .EXTN   BMBFG
                        .EXTN   TDV1
                        .EXTN   TRG1
                        .EXTN   FFSB
                        .EXTN   FFAD
                        .EXTN   FFDV


00000'102400 NRLA:      SUB     0,0     ;ZERO IN AC0
00001'000402            JMP     ENTR1   ;JUMP AROUND
00002'102520 NRLB:      SUBZL   0,0     ;ONE IN AC0
00003'054522 ENTR1:     STA     3,RETRN ;SAVE RETURN ADR.
00004'040522            STA     0,NRLPR ;N-R POINTER
00005'102400            SUB     0,0     ;ZERO IN AC0
00006'040521            STA     0,DVBBF ;DERIV. BOMB FLAG
00007'040550            STA     0,BBMXF
00010'042526            STA     @0,.BMFG;RESET Z MIN BOMB FLAG
00011'031400            LDA     2,0,3   ;GET DATA TB.ADR.
00012'050516            STA     2,DATAD
00013'050421            STA     2,DTAD1
00014'050423            STA     2,DTAD2
00015'020514            LDA     0,INC1  ;GET Z VAL. ADR. INCREM.
00016'143000            ADD     2,0     ;Z VAL. ADR.
00017'040475            STA     0,ZAD1
00020'040475            STA     0,ZAD2
00021'040542            STA     0,ZVAD3
00022'020510            LDA     0,INC2  ;GET ACT. HOR. RNG. ADR. INCR.
00023'143000            ADD     2,0     ;ACT. HOR. RNG. ADR.
00024'040435            STA     0,HRAD1
00025'020506            LDA     0,INC3  ;GET Z MAX. ADR. INCREM.
00026'143000            ADD     2,0     ;Z MAX. ADR.
00027'040533            STA     0,ZMXA1
00030'004530            JSR     TSMX    ;MAX. LIMIT TEST
00031'014475            DSZ     NRLPR   ;N-R. LOOPS POINTER
00032'000404            JMP     ENTR2   ;ONE N-R
00033'006501            JSR     @,NRMB  ;MULTIPLE N-R
00034'000000 DTAD1:     0
00035'000403            JMP     ENTR3   ;JUMP AROUND
00036'006477 ENTR2:     JSR     @,NRMA  ;FIRST N-R
00037'000000 DTAD2:     0
00040'022476 ENTR3:     LDA     @0,.BMFG        ;MIN.Z LIMIT BOMB FLAG
00041'101004            MOV     0,0,SZR ;SKIP IF Z VAL. O.K.
00042'000456            JMP     ENRLP   ;END BY BOMBING
00043'030474            LDA     2,.TDV1 ;GET TOT. DERIV. ADR.
00044'021001            LDA     0,1,2   ;GET TOT. DERIV SIGN
00045'030463            LDA     2,DATAD ;GET DATA TB. ADR.
00046'025031            LDA     1,31,2  ;GET DERIV SIGN BIT
00047'176620            SUBZR   3,3     ;EXTRACT SIGN BIT ONLY
```

```
0002  NRLAB
 00050'117400          AND     0.3
 00051'137000          ADD     1.3
 00052'152400          SUB     2.2      ;ZERO IN AC2
 00053'175132          MOVZL#  3.3.SZC  ;SKIP IF DERIV. O.K.
 00054'152520          SUBZL   2.2      ;ONE IN AC2
 00055'050452          STA     2.DVBBF  ;DERIV. BOMB FLAG
 00056'151004          MOV     2.2.SZR  ;SKIP IF DERIV. O.K.
 00057'000441          JMP     ENRLP    ;END BY BOMBING
 00060'006460          JSR     @.FSUB   ;(ACT-CAL.)HOR. RNG.
 00061'000000 HRAD1:   0
 00062'177777          TRG1
 00063'000141'         TEMA1
 00064'030455          LDA     2.TEMA1
 00065'024455          LDA     1.TEMA2
 00066'020455          LDA     0.TEMA3
 00067'125113          MOVL#   1.1.SNC
 00070'000404          JMP     ENTR5
 00071'100404          NEG     0.0.SZR
 00072'124001          COM     1.1.SKP
 00073'124400          NEG     1.1
 00074'050450 ENTR5:   STA     2.TEMC1
 00075'044450          STA     1.TEMC2
 00076'040450          STA     0.TEMC3
 00077'006441          JSR     @.FSUB   ;ABOVE-LIMIT
 00100'000144'         TEMC1
 00101'000147'         DLRG1
 00102'000144'         TEMC1
 00103'020442          LDA     0.TEMC2  ;GET RESULT
 00104'101102          MOVL    0.0.SZC  ;SKIP IF OUTSIDE LIMIT
 00105'000413          JMP     ENRLP    ;END EARLY
 00106'006444          JSR     @.FDIV   ;((ACT.-CAL.)HOR. RNG.)/DERIV.
 00107'000141'         TEMA1
 00110'177777          TDV1
 00111'000153'         TEMB1
 00112'006444          JSR     @.FADD   ;ABOVE + Z VALUE
 00113'000153'         TEMB1
 00114'000000 ZAD1:    0
 00115'000000 ZAD2:    0
 00116'004442          JSR     TSMX     ;MAX. LIMIT TEST
 00117'000404          JMP     ENTR4    ;END NATURALLY
 00120'030410 ENRLP:   LDA     2.DATAD  ;GET DATA TB. ADR.
 00121'102520          SUBZL   0.0      ;ONE IN AC0
 00122'041035          STA     0.35.2   ;STORE ONE FOR NO. N.R.
 00123'034402 ENTR4:   LDA     3.RETRN  ;GET RETURN ADR.
 00124'001401          JMP     1.3      ;RETURN
 00125'000000 RETRN:   0
 00126'000000 NRLPR:   0
 00127'000000 DVBBF:   0
 00130'000000 DATAD:   0
 00131'000023 INC1:    23
 00132'000001 INC2:    1
 00133'000036 INC3:    36
 00134'177777 .NRMB:   NRMB
 00135'177777 .NRMA:   NRMA
 00136'177777 .BMFG:   BMBFG
 00137'000110'.TDV1:   TDV1
 00140'177777 .FSUB:   FF3B
 00141'000000 TEMA1:   0
 00142'000000 TEMA2:   0
```

LISTING C11 (Continued)

```
0003  NRLAB
 00143'000000 TEMA3:  0
 00144'000000 TEMC1:  0
 00145'000000 TEMC2:  0
 00146'000000 TEMC3:  0
 00147'037775 DLRG1:  037775
 00150'077777         077777
 00151'177777         177777
 00152'177777 .FDIV:  FFDV
 00153'000000 TEMB1:  0
 00154'000000 TEMB2:  0
 00155'000000         0
 00156'177777 .FADD:  FFAD
 00157'000000 BBMXF:  0
 00160'054427 TSMX:   STA     3.RETUN ;SAVE RETURN ADR.
 00161'006757         JSR     @.FSUB  ;Z MAX. - Z VAL.
 00162'000000 ZMXA1:  0
 00163'000000 ZVAD3:  0
 00164'000153'        TEMB1
 00165'126400         SUB     1.1     ;ZERO IN AC1
 00166'020766         LDA     0.TEMB2 ;GET SIGN OF ABOVE
 00167'101102         MOVL    0.0.SZC ;SKIP IF Z VAL.O.K.
 00170'125400         INC     1.1     ;ONE
 00171'044766         STA     1.BBMXF ;MX. VAL. BOMB FLAG
 00172'125005         MOV     1.1.SNR ;SKIP IF BOMBED
 00173'000412         JMP     ENDRR   ;END
 00174'030767         LDA     2.ZVAD3 ;GET Z VAL. ADR
 00175'034765         LDA     3.ZMXA1 ;GET Z MAX. ADR
 00176'021400         LDA     0.0.3   ;MAKE Z VAL. Z MAX.
 00177'041000         STA     0.0.2
 00200'021401         LDA     0.1.3
 00201'041001         STA     0.1.2
 00202'021402         LDA     0.2.3
 00203'041002         STA     0.2.2
 00204'000714         JMP     ENRLP
 00205'034402 ENDRR:  LDA     3.RETUN ;GET RETURN ADR.
 00206'001400         JMP     0.3     ;RETURN
 00207'000000 RETUN:  0
                      .END
```

LISTING C11 (Continued)

NRMA (NRMA AND NRMB) SUBROUTINE

1. The NRMA subroutine has two entry points NRMA and NRMB. NRMA is used to extract the parameters from a ray path code word during its first pass through a Newton-Raphson calculation. NRMB is used for further Newton-Raphson calculations on the same ray path that first used NRMA.

2. NRLAB and NR1A2

3.
```
          JSR@ .NRMA
          BGDAT
    .
    .
    .
.NRMA:    NRMA
          JSR@ .NRMB
          BGDAT
    .
    .
    .
.NRMB:    NRMB
```

4. FIN1, FIN2, and FQ1.

5. CODEW

6. TPNUM, BTNUM, DIRMD, NUMCY, and SGNDV

7. See Figure C12.

8. See Listing C12.

9. NRMB is used to save some computational time over NRMA.

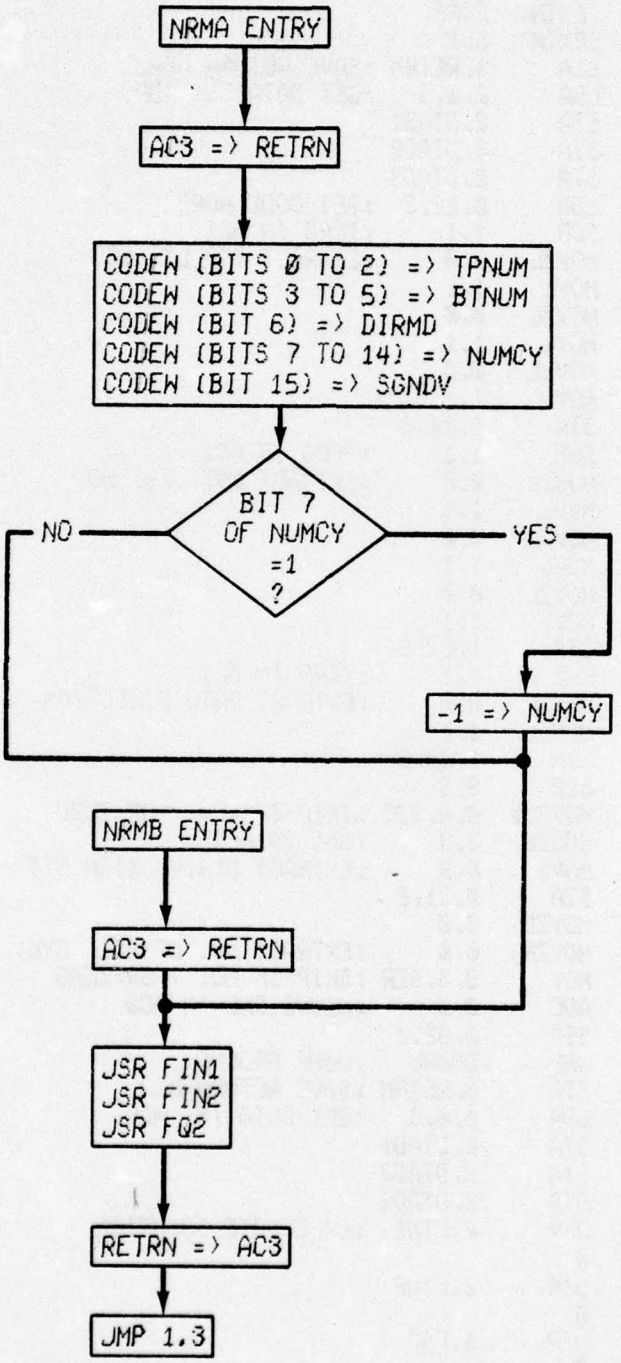

NRMA ENTRY
AC3 => RETRN
CODEW (BITS Ø TO 2) => TPNUM
CODEW (BITS 3 TO 5) => BTNUM
CODEW (BIT 6) => DIRMD
CODEW (BITS 7 TO 14) => NUMCY
CODEW (BIT 15) => SGNDV
BIT 7 OF NUMCY =1 ?
NO
YES
-1 => NUMCY
NRMB ENTRY
AC3 => RETRN
JSR FIN1
JSR FIN2
JSR FQ2
RETRN => AC3
JMP 1,3

FIG. C12

```
0001  NRMA
                        .NREL
                        .TITL   NRMA    ;03/08/74
        000010          .RDX    8
                        .ENT    NRMA
                        .ENT    NRMB
                        .EXTN   FIN1
                        .EXTN   FIN2
                        .EXTN   FQ2
00000'054462 NRMA:      STA     3,RETRN ;SAVE RETURN ADR.
00001'031400            LDA     2,@3    ;GET DATA TB. ADR.
00002'050451            STA     2,DTAD1
00003'050452            STA     2,DTAD2
00004'050453            STA     2,DTAD3
00005'021022            LDA     0,22,2  ;GET CODE WORD
00006'126400            SUB     1,1     ;ZERO IN AC1
00007'101120            MOVZL   0,0     ;EXTRACT TOP LT. NO.
00010'125100            MOVL    1,1
00011'101120            MOVZL   0,0
00012'125100            MOVL    1,1
00013'101120            MOVZL   0,0
00014'125100            MOVL    1,1
00015'045026            STA     1,26,2
00016'126400            SUB     1,1     ;ZERO IN AC1
00017'101120            MOVZL   0,0     ;EXTRACT BOT. LY. NO.
00020'125100            MOVL    1,1
00021'101120            MOVZL   0,0
00022'125100            MOVL    1,1
00023'101120            MOVZL   0,0
00024'125100            MOVL    1,1
00025'045027            STA     1,27,2
00026'126400            SUB     1,1     ;ZERO IN AC1
00027'101120            MOVZL   0,0     ;EXTRACT PATH DIRECTION
00030'125100            MOVL    1,1
00031'045030            STA     1,30,2
00032'176400            SUB     3,3
00033'101132            MOVZL#  0,0,SZC ;SKIP IF NO. > OR=ZERO
00034'176520            SUBZL   3,3     ;ONE IN AC3
00035'101300            MOVS    0,0     ;EXTRACT DERIV. SIGN BIT
00036'041031            STA     0,31,2
00037'101120            MOVZL   0,0
00040'101220            MOVZR   0,0     ;EXTRACT NO. OF HALF CYC.
00041'175004            MOV     3,3,SZR ;SKIP IF NO. > OR=ZERO
00042'102000            ADC     0,0     ;MINUS ONE IN AC0
00043'041032            STA     0,32,2
00044'000406            JMP     DONRL   ;JUMP AROUND
00045'054415 NRMB:      STA     3,RETRN ;SAVE RETURN ADR.
00046'031400            LDA     2,@3    ;GET DATA TB. ADR.
00047'050404            STA     2,DTAD1
00050'050405            STA     2,DTAD2
00051'050406            STA     2,DTAD3
00052'006411 DONRL:     JSR     @.FIN1  ;CALCULATE SOLUTION
00053'000000 DTAD1:     0
00054'006410            JSR     @.FIN2
00055'000000 DTAD2:     0
00056'006407            JSR     @.FQ2
00057'000000 DTAD3:     0
00060'034402            LDA     3,RETRN ;GET RETURN ADR.
00061'001401            JMP     1,3     ;RETURN
00062'000000 RETRN:     0
```

LISTING C12
C-104

```
0002  NRMA
 00063'177777 .FIN1:  FIN1
 00064'177777 .FIN2:  FIN2
 00065'177777 .FQ2:   FQ2
                      .END
```

LISTING C12 (Continued)

FIN1 SUBROUTINE

1. The FIN1 subroutine computes a table of values used by the FIN2 subroutine. This subroutine is one of the three main computational routines.

2. NRMA, and MNMX

3.
```
        JSR@ .FIN1
        BGDAT
          .
          .
          .
.FIN1:  FIN1
```

4. FPMP

5. LYVEL, TGSQ1, SNSQ1, ZVAL1, FN1SK, FN2SK, TPNUM, and BTNUM

6. RGP, DVP, TMP, SRGP, TRGP, SDVP, TDVP, STMP, TTMP, and BMBFG

7. See Figure C13.

8. See Listing C13.

9. a) This subroutine uses the FN1SK and FN2SK flags to save computation time.

   b) If the value of z exceeds a certain maximum value then an approximation is used to compute the tables used by FIN2. The approximation is for $\sqrt{z^2 - v^2}$ which is $z - v^2/2z$ when z is >> v. Since FIN2 subtracts one value in the table from another the z part of the approximation is discarded.

c) If the value of z is equal to or less than a value of v in its calculation of $\sqrt{z^2 - v^2}$, then the solution is invalid and BMBFG is set to one.

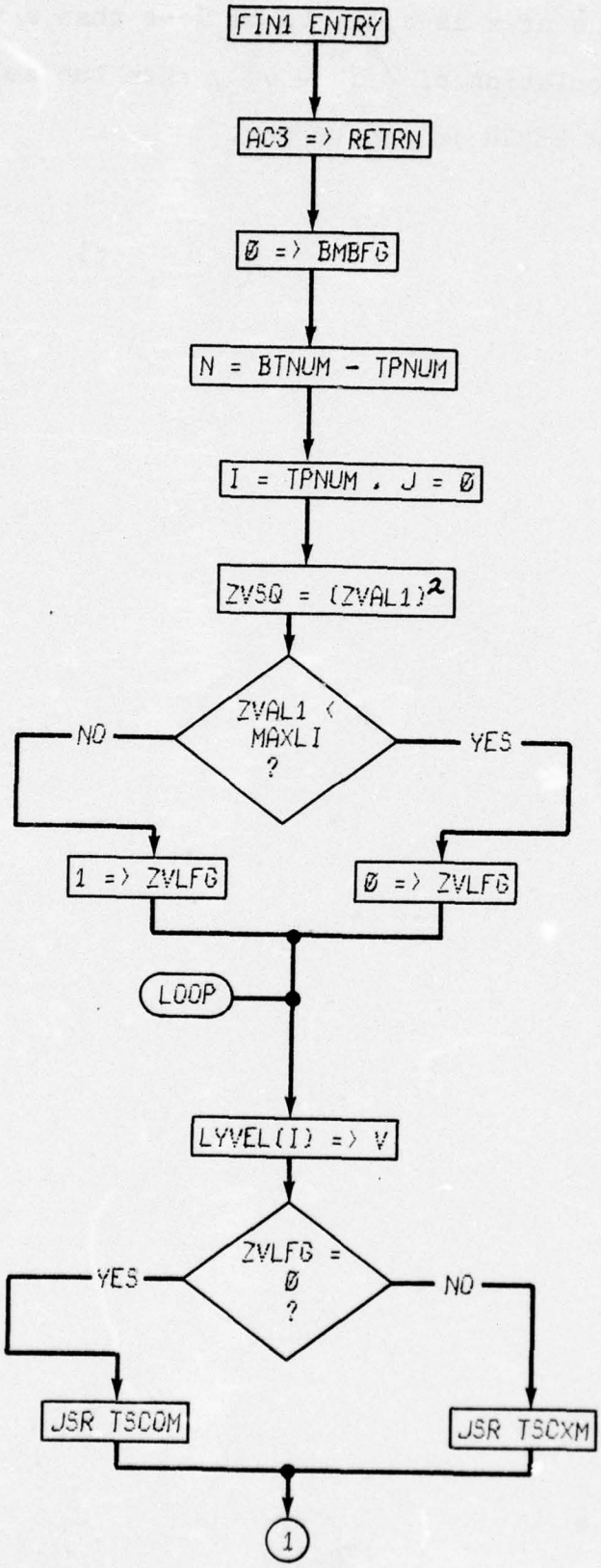

FIN1 ENTRY
AC3 => RETRN
Ø => BMBFG
N = BTNUM - TPNUM
I = TPNUM , J = Ø
ZVSQ = (ZVAL1)2
ZVAL1 < MAXLI ?
NO
YES
1 => ZVLFG
Ø => ZVLFG
LOOP
LYVEL(I) => V
ZVLFG = Ø ?
YES
NO
JSR TSCOM
JSR TSCXM
1

FIG. C13

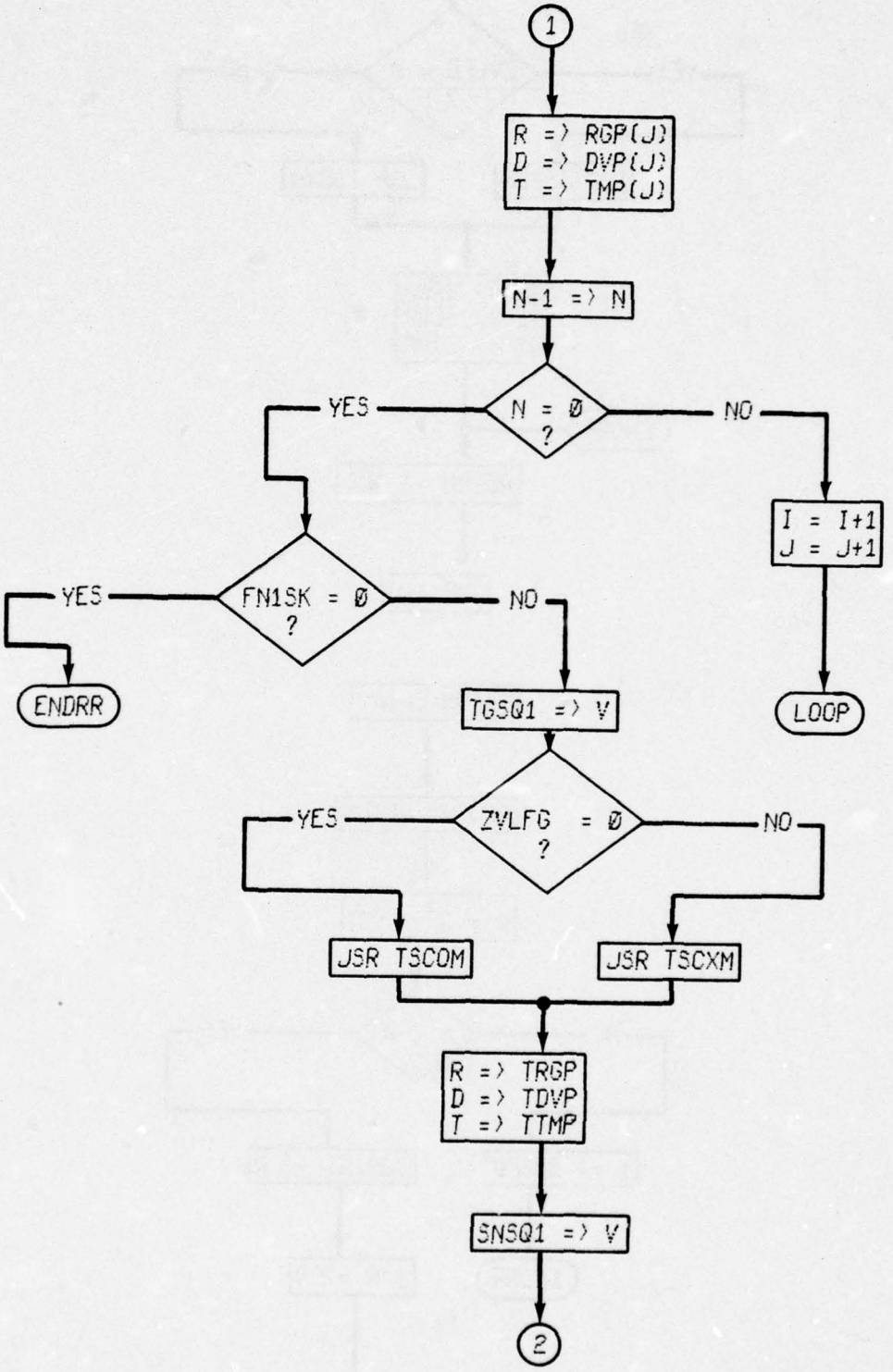


FIG. C13 (CONTINUED)

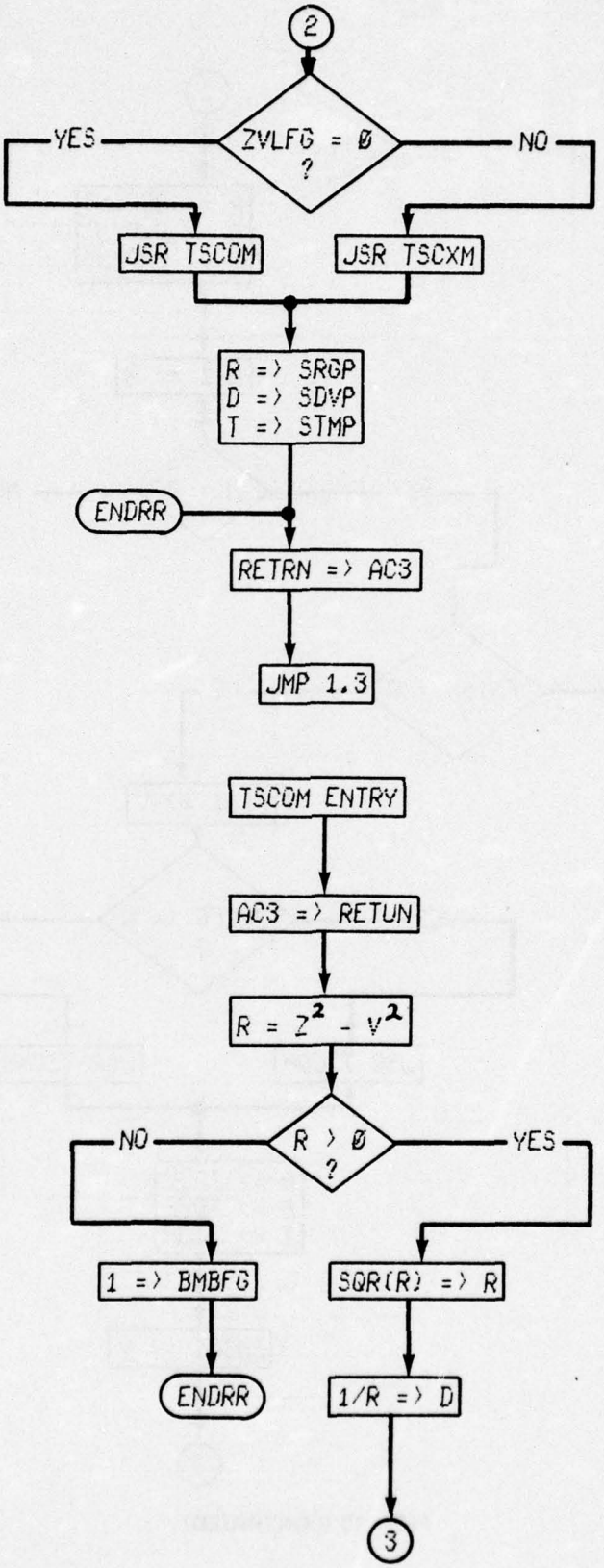
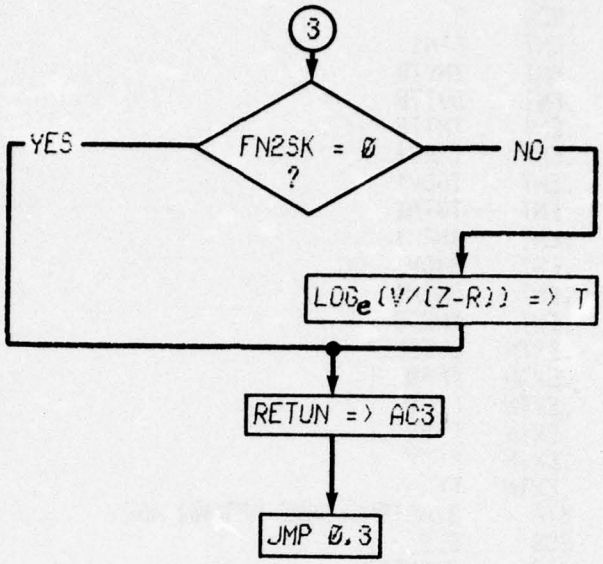


FIG. C13 (CONTINUED)



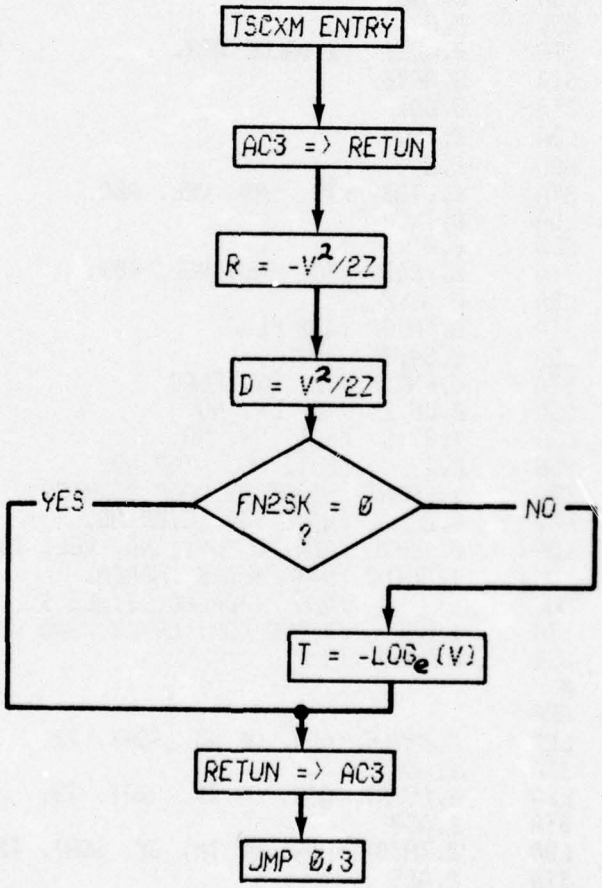


FIG. C13 (CONTINUED)

```
                    .NREL
                    .TITL   FIN1    ;03/15/74
          000010    .RDX    8
                    .ENT    FIN1
                    .ENT    ZMVTB
                    .ENT    DVTTB
                    .ENT    TMTTB
                    .ENT    TGRG1
                    .ENT    TGDV1
                    .ENT    TGTM1
                    .ENT    SNRG1
                    .ENT    SNDV1
                    .ENT    SNTM1
                    .ENT    BMBFG
                    .EXTN   LYVEL
                    .EXTN   FFSQ
                    .EXTN   FFSB
                    .EXTN   FFSR
                    .EXTN   FFDV
                    .EXTN   FFLN
00000'054537 FIN1:  STA     3,RETRN ;SAVE RETURN ADR.
00001'102400        SUB     0,0
00002'040536        STA     0,BMBFG
00003'031400        LDA     2,0,3   ;GET DATA TB. ADR.
00004'050535        STA     2,DATAD
00005'020535        LDA     0,INC1
00006'143000        ADD     2,0
00007'040427        STA     0,ADZ1  ;Z VALUE ADR.
00010'040437        STA     0,ADZ2
00011'040544        STA     0,AD1
00012'020531        LDA     0,INC3
00013'143000        ADD     2,0
00014'040531        STA     0,.TASV ;TG. SND. VEL. ADR.
00015'020527        LDA     0,INC4
00016'143000        ADD     2,0
00017'040527        STA     0,.SOSV ;TG. SND. VEL. ADR.
00020'021033        LDA     0,33,2
00021'040526        STA     0,FN1SK ;A+B FLAG
00022'021034        LDA     0,34,2
00023'040525        STA     0,FN2SK ;TM. DY. FLAG
00024'021026        LDA     0,26,2  ;TOP LY. NO.
00025'025027        LDA     1,27,2  ;BOT. LY. NO.
00026'106400        SUB     0,1     ;BOT. NO. -TOP NO.
00027'044522        STA     1,LPCNT ;STORE AS LOOP COUNTER
00030'111000        MOV     0,2     ;MOVE TOP LAYER NO.
00031'020521        LDA     0,.LYVL ;ADR. OF LY. SND. VEL. TB.
00032'024522        LDA     1,DBINC ;DATA BLOCK INCREM.
00033'073301        MUL             ;ADR. +TOP NO. TIMES 3
00034'044522        STA     1,AD2   ;STORE ADR. OF LY. SND VEL.
00035'006534        JSR     @.FSQQ  ;Z^2
00036'000000 ADZ1:  0
00037'000162'       AD6
00040'030525        LDA     2,ZMVST ;ADR. OF RG. SQRT. TB.
00041'050516        STA     2,AD3
00042'030524        LDA     2,DVTBT ;ADR. OF DV. SQRT. TB.
00043'050515        STA     2,AD4
00044'030523        LDA     2,TMTBT ;ADR. OF TM. DY. SQRT. TB.
00045'050514        STA     2,AD5
00046'006522        JSR     @.FSUB  ;Z - ZMAX. LIM.
```

```
00047'000000 ADZ2:   Ø              ;Z ADR.
00050'000172'        MAXL1          ;ZMAX LIM. ADR.
00051'000175'        TEMA1          ;RESULT ADR.
00052'020524         LDA     Ø,TEMA2 ;GET SIGN OF RESULT
00053'126400         SUB     1,1     ;ZERO IN AC1
00054'101103         MOVL    Ø,Ø,SNC ;SKIP IF Z< ZMAX. LIM.
00055'125400         INC     1,1
00056'044522         STA     1,ZVLFG ;Z VAL. LIM. FLAG
00057'024521 LOOP:   LDA     1,ZVLFG
00060'125004         MOV     1,1,SZR ;SKIP IF Z< ZMAX. LIM.
00061'006472         JSR     Ø,TSCX  ;> ZMAX. LIM.
00062'004525         JSR     TSCOM   ;< ZMAX. LIM.
00063'024471         LDA     1,DBINC ;GET DATA BASE INCREM.
00064'020472         LDA     Ø,AD2   ;SET UP NEXT ADR.
00065'123000         ADD     1,Ø
00066'040470         STA     Ø,AD2
00067'020470         LDA     Ø,AD3
00070'123000         ADD     1,Ø
00071'040466         STA     Ø,AD3
00072'020466         LDA     Ø,AD4
00073'123000         ADD     1,Ø
00074'040464         STA     Ø,AD4
00075'020464         LDA     Ø,AD5
00076'123000         ADD     1,Ø
00077'040462         STA     Ø,AD5
00100'014451         DSZ     LPCNT   ;SKIP WHEN DONE
00101'000756         JMP     LOOP    ;LOOP AGAIN
00102'020445         LDA     Ø,FN1SK ;SKIP A*B RAY CAL. FLAG
00103'101005         MOV     Ø,Ø,SNR
00104'000431         JMP     ENDRR   ;END
00105'020440         LDA     Ø,.TASV ;ADR. OF TARG. SND. VEL.
00106'040450         STA     Ø,AD2
00107'020472         LDA     Ø,.TGRG ;ADR. OF TARG. RNG. SQRT. TB.
00110'040447         STA     Ø,AD3
00111'020471         LDA     Ø,.TGDV ;ADR. OF TARG. DV. SQRT. TB.
00112'040446         STA     Ø,AD4
00113'020470         LDA     Ø,.TGTM ;ADR. OF TARG. TM. SQRT. TB.
00114'040445         STA     Ø,AD5
00115'024463         LDA     1,ZVLFG ;Z VAL. LIM. FLAG
00116'125004         MOV     1,1,SZR ;SKIP IF Z < ZMAX. LIM.
00117'004554         JSR     TSCXM   ;> ZMAX. LIM.
00120'004467         JSR     TSCOM   ;< ZMAX. LIM.
00121'020425         LDA     Ø,.SOSV ;ADR. OF SONO. SND. VEL.
00122'040434         STA     Ø,AD2
00123'020461         LDA     Ø,.SNRG ;ADR. OF SONO. RNG. SQRT. TB.
00124'040433         STA     Ø,AD3
00125'020460         LDA     Ø,.SNDV ;ADR. OF SONO. DV. SQRT. TB.
00126'040432         STA     Ø,AD4
00127'020457         LDA     Ø,.SNTM ;ADR. OF SONO. TM. SQRT. TB.
00130'040431         STA     Ø,AD5
00131'024447         LDA     1,ZVLFG ;Z VAL. LIM. FLAG
00132'125004         MOV     1,1,SZR ;SKIP IF Z < ZMAX. LIM.
00133'004540         JSR     TSCXM   ;> ZMAX.  LIM.
00134'004453         JSR     TSCOM   ;< ZMAX. LIM.
00135'034402 ENDRR:  LDA     3,RETRN
00136'001401         JMP     1,3
00137'000000 RETRN:  Ø
00140'000000 BMBFG:  Ø
00141'000000 DATAD:  Ø
```

LISTING C13 (Continued)

```
00142'000023 INC1:   23
00143'000007 INC3:   7
00144'000004 INC4:   4
00145'000000 .TASV:  0
00146'000000 .SOSV:  0
00147'000000 FN1SK:  0
00150'000000 FN2SK:  0
00151'000000 LPCNT:  0
00152'177777 .LYVL:  LYVEL
00153'000273'.TSCX:  TSCXM
00154'000003 DBINC:  3
00155'000000 AD1:    0
00156'000000 AD2:    0
00157'000000 AD3:    0
00160'000000 AD4:    0
00161'000000 AD5:    0
00162'000000 AD6:    0
00163'000000         0
00164'000000         0
00165'000405'ZMVST:  ZMVTB
00166'000421'DVTBT:  DVTTB
00167'000435'TMTBT:  TMTTB
00170'177777 .FSUB:  FFSB
00171'177777 .FSQQ:  FFSQ
00172'040020 MAXL1:  040020
00173'077777         077777
00174'177777         177777
00175'000000 TEMA1:  0
00176'000000 TEMA2:  0
00177'000000         0
00200'000000 ZVLFG:  0
00201'000451'.TGRG:  TGRG1
00202'000454'.TGDV:  TGDV1
00203'000457'.TGTM:  TGTM1
00204'000462'.SNRG:  SNRG1
00205'000465'.SNDV:  SNDV1
00206'000470'.SNTM:  SNTM1
00207'054552 TSCOM:  STA     3.RETUN ;SAVE RETURN ADR.
00210'020745         LDA     0.AD1
00211'040446         STA     0.AD7
00212'020744         LDA     0.AD2
00213'040413         STA     0.AD8
00214'040447         STA     0.AD9
00215'020742         LDA     0.AD3
00216'040430         STA     0.AD10
00217'040432         STA     0.AD11
00220'040440         STA     0.AD12
00221'020737         LDA     0.AD4
00222'040430         STA     0.AD13
00223'020736         LDA     0.AD5
00224'040444         STA     0.AD14
00225'006535         JSR     @.FSQR  ;V^2
00226'000000 AD8:    0
00227'000374'        AD15
00230'006740         JSR     @.FSUB  ;Z^2-V^2
00231'000162'        AD6
00232'000374'        AD15
00233'000363'        AD16
00234'020530         LDA     0.ADX   ;SIGN OF RESULT
```

LISTING C13 (Continued)

```
00235'101005          MOV     0,0,SNR ;SKIP IF NON ZERO
00236'000403          JMP     ENT1
00237'101103          MOVL    0,0,SNC ;SKIP IF NEGATIVE
00240'000404          JMP     ARND
00241'102520 ENT1:    SUBZL   0,0     ;SET FLAG
00242'040676          STA     0,BMBFG
00243'000672          JMP     ENDRR   ;BOMB OUT
00244'006522 ARND:    JSR     @.FSQT  ;SQRT (Z^2-V^2)
00245'000363'         AD16
00246'000000 AD10:    0
00247'006520          JSR     @.FDIV  ;1/SQRT(Z^2-V^2)
00250'000370'         AD17
00251'000000 AD11:    0
00252'000000 AD13:    0
00253'020675          LDA     0,FN2SK ;SKIP TM. FLAG
00254'101005          MOV     0,0,SNR
00255'000414          JMP     ENLOP
00256'006712          JSR     @.FSUB  ;Z-SQRT(Z^2-V^2)
00257'000000 AD7:     0
00260'000000 AD12:    0
00261'000363'         AD16
00262'006505          JSR     @.FDIV  ;V/(ABOVE)
00263'000000 AD9:     0
00264'000363'         AD16
00265'000374'         AD15
00266'006505          JSR     @.FLNE  ;LN(ABOVE)
00267'000374'         AD15
00270'000000 AD14:    0
00271'034470 ENLOP:   LDA     3,RETUN ;GET RETURN ADR.
00272'001400          JMP     0,3     ;RETURN
00273'054466 TSCXM:   STA     3,RETUN ;SAVE RETURN ADR.
00274'020662          LDA     0,AD2
00275'040412          STA     0,AD19
00276'040447          STA     0,AD25
00277'020660          LDA     0,AD3
00300'040424          STA     0,AD20
00301'040425          STA     0,AD24
00302'020656          LDA     0,AD4
00303'040425          STA     0,AD21
00304'020655          LDA     0,AD5
00305'040441          STA     0,AD22
00306'006454          JSR     @.FSQR  ;V^2
00307'000000 AD19:    0
00310'000377'         AD23
00311'034644          LDA     3,AD1
00312'021400          LDA     0,0,3
00313'025401          LDA     1,1,3
00314'031402          LDA     2,2,3
00315'101400          INC     0,0
00316'040464          STA     0,DBZ1
00317'044464          STA     1,DBZ2
00320'050464          STA     2,DBZ3
00321'006446          JSR     @.FDIV  ;V^2/2Z
00322'000377'         AD23
00323'000402'         DBZ1
00324'000000 AD20:    0
00325'006442          JSR     @.FDIV  ;V^2/2Z^3
00326'000000 AD24:    0
00327'000162'         AD6
```

LISTING C13 (Continued)

```
00330'000000 AD21:   0
00331'030775         LDA     2,AD20
00332'021001         LDA     0,1,2
00333'025002         LDA     1,2,2
00334'124404         NEG     1,1,SZR ;-V^2/2Z
00335'100001         COM     0,0,SKP
00336'100400         NEG     0,0
00337'041001         STA     0,1,2
00340'045002         STA     1,2,2
00341'020607         LDA     0,FN2SK
00342'101005         MOV     0,0,SNR
00343'000414         JMP     EXLOP
00344'006427         JSR     @.FLNE  ;LN(V)
00345'000000 AD25:   0
00346'000000 AD22:   0
00347'030777         LDA     2,AD22
00350'021001         LDA     0,1,2
00351'025002         LDA     1,2,2
00352'124404         NEG     1,1,SZR ;-LN(V)
00353'100001         COM     0,0,SKP
00354'100400         NEG     0,0
00355'041001         STA     0,1,2
00356'045002         STA     1,2,2
00357'034402 EXLOP:  LDA     3,RETUN
00360'001401         JMP     1,3
00361'000000 RETUN:  0
00362'000171'.FSQR:  FFSQ
00363'000000 AD16:   0
00364'000000 ADX:    0
00365'000000         0
00366'177777 .FSQT:  FFSR
00367'177777 .FDIV:  FFDV
00370'040000 AD17:   040000  ;ONE
00371'077777         077777
00372'177777         177777
00373'177777 .FLNE:  FFLN
00374'000000 AD15:   0
00375'000000         0
00376'000000         0
00377'000000 AD23:   0
00400'000000         0
00401'000000         0
00402'000000 DBZ1:   0
00403'000000 DBZ2:   0
00404'000000 DBZ3:   0
00405'000000 ZMVTB:  0
      000013         .BLK    13
00421'000000 DVTTB:  0
      000013         .BLK    13
00435'000000 TMTTB:  0
      000013         .BLK    13
00451'000000 TGRG1:  0
00452'000000         0
00453'000000         0
00454'000000 TGDV1:  0
00455'000000         0
00456'000000         0
00457'000000 TGTM1:  0
00460'000000         0
```

LISTING C13 (Continued)

```
00461'000000          0
00462'000000 SNRG1:   0
00463'000000          0
00464'000000          0
00465'000000 SNDV1:   0
00466'000000          0
00467'000000          0
00470'000000 SNTM1:   0
00471'000000          0
00472'000000          0
                      .E  ND
```

LISTING C13 (Continued)

FIN2 SUBROUTINE

1. The FIN2 subroutine uses the tables computed in FIN1 to calculate the A, B, and C parts of the ray path horizontal range, derivative, and time delay. This subroutine is one of the three main computational routines.

2. NRMA and MNMX

3.
```
        JSR@ .F1N2
        BGDAT
    .
    .
    .
.FIN2:  F1N2
```

4. FPMP

5. GDTBL, ZVAL1, FN1SK, RGP, DVP, TMP, SRGP, TRGP, SDVP, TDVP, STMP, TTMP, TPNUM, AND BTNUM.

6. ARG1, BRG1, CRG1, ADV1, BDV1, CDV1, ATM1, BTM1, and CTM1.

7. See Figure C14.

8. See Listing C14.

9. a) This subroutine uses the FN1SK flag to save computation time.

   b) The A, B, and C parts of the ray path are computed by adding up the contributions of the circular segments in each of the

layers through which the ray path travels. This is accomplished using the Type 1, 2, and 3 circular segment equations.

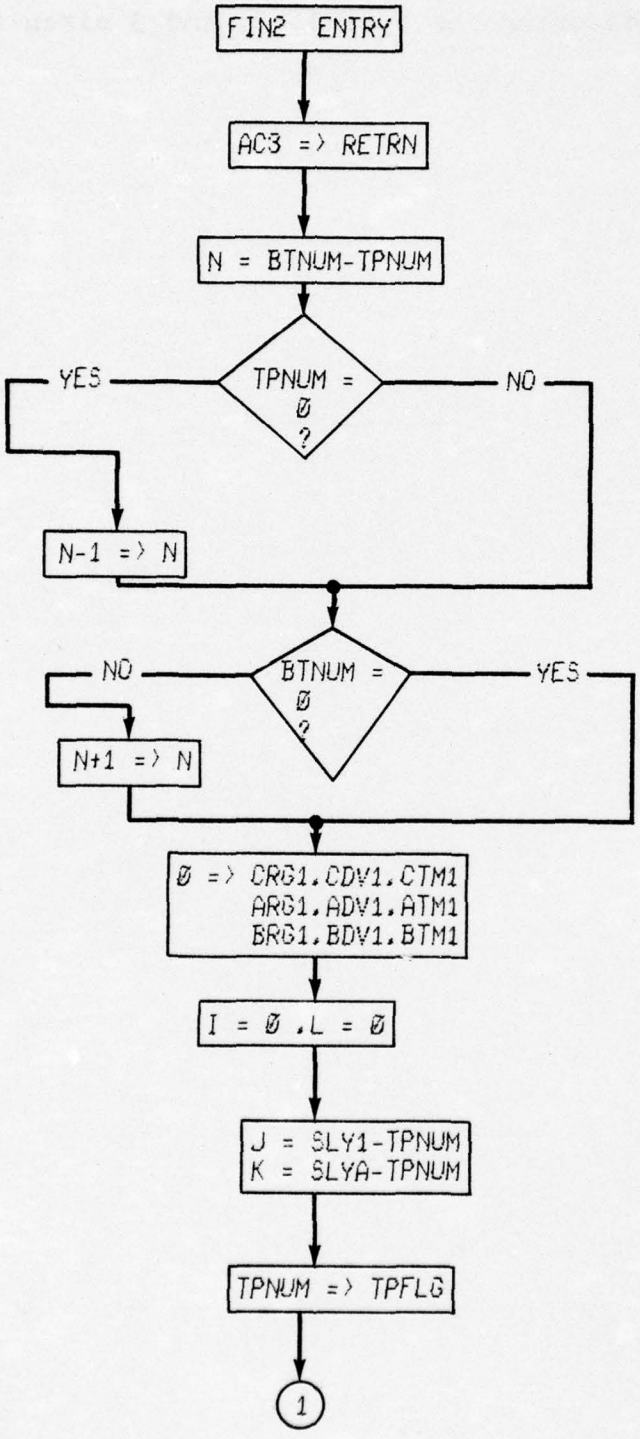

FIN2 ENTRY
AC3 => RETRN
N = BTNUM-TPNUM
TPNUM = Ø ?
YES
NO
N-1 => N
BTNUM = Ø ?
NO
YES
N+1 => N
Ø => CRG1.CDV1.CTM1
ARG1.ADV1.ATM1
BRG1.BDV1.BTM1
I = Ø .L = Ø
J = SLY1-TPNUM
K = SLYA-TPNUM
TPNUM => TPFLG
1

FIG. C14

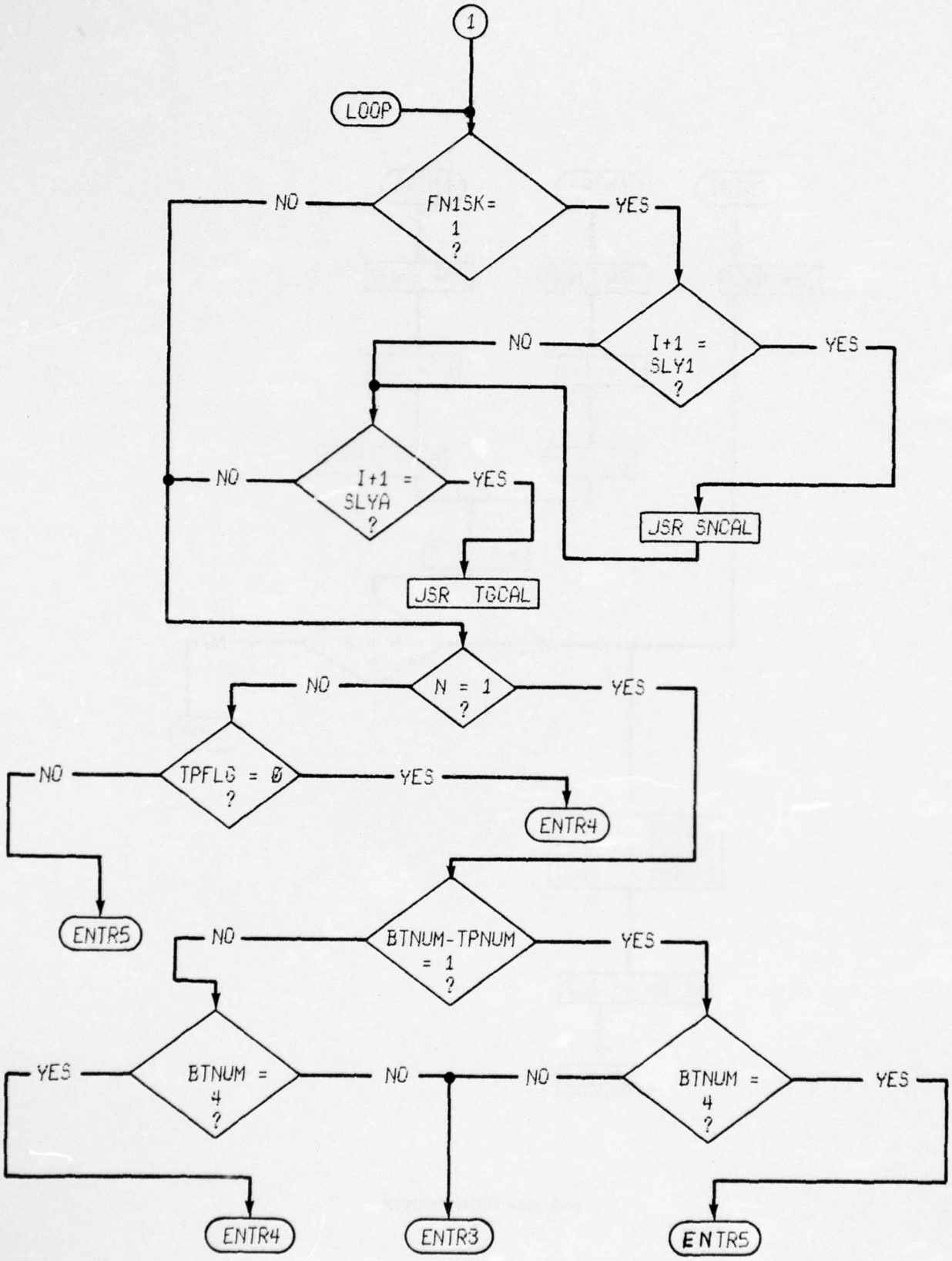


FIG. C14 (CONTINUED)

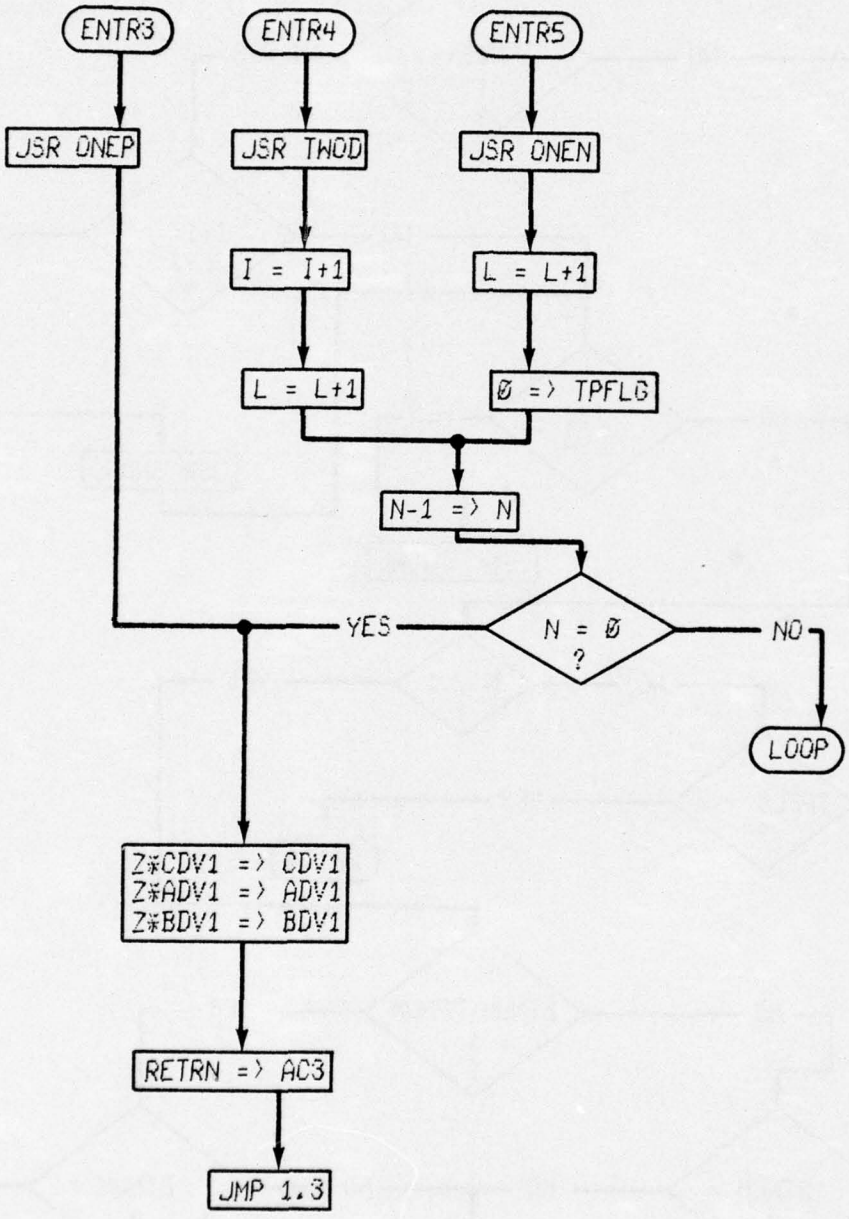


FIG. C14 (CONTINUED)

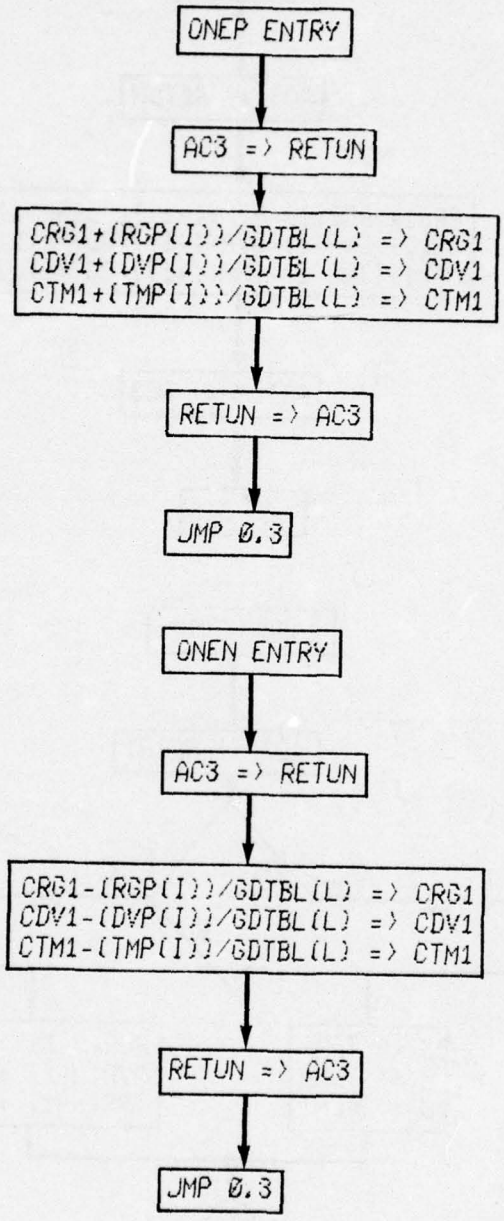


FIG. C14 (CONTINUED)

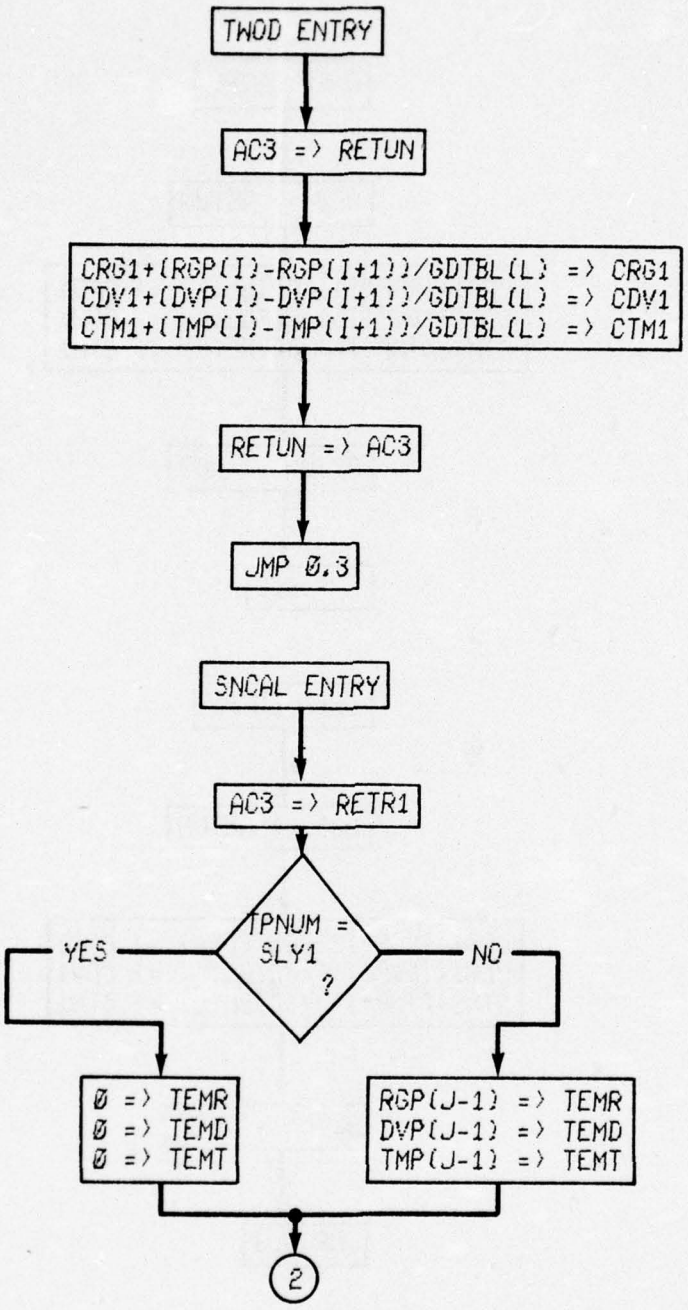


FIG. C14 (CONTINUED)

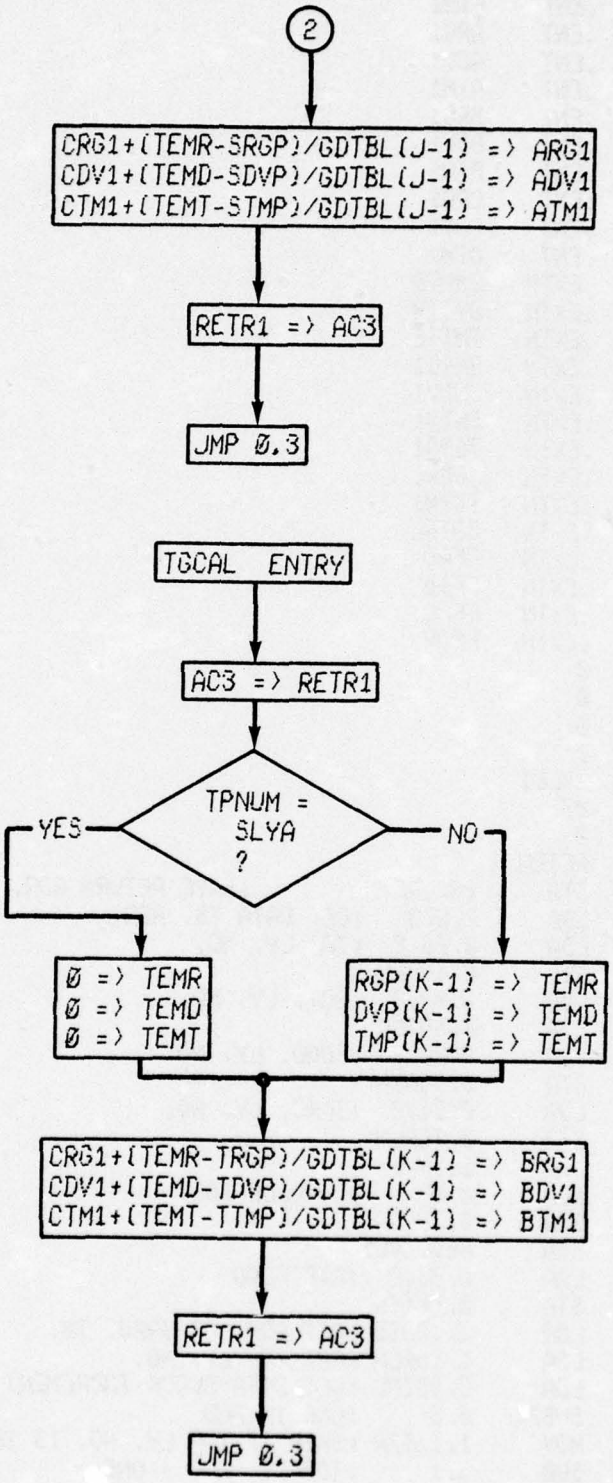


FIG. C14 (CONTINUED)

```
0001  FIN2
                        .NREL
                        .TITL   FIN2    ;03/21/74
        000010          .RDX    8
                        .ENT    FIN2
                        .ENT    ARG1
                        .ENT    ADV1
                        .ENT    ATM1
                        .ENT    BRG1
                        .ENT    BDV1
                        .ENT    BTM1
                        .ENT    CRG1
                        .ENT    CDV1
                        .ENT    CTM1
                        .EXTN   ZMVTB
                        .EXTN   DVTTB
                        .EXTN   TMTTB
                        .EXTN   SNRG1
                        .EXTN   SNDV1
                        .EXTN   SNTM1
                        .EXTN   TGRG1
                        .EXTN   TGDV1
                        .EXTN   TGTM1
                        .EXTN   GDTBL
                        .EXTN   FFAD
                        .EXTN   FFSB
                        .EXTN   FFML
                        .EXTN   FFDV
00000'000000 TOPLN:     0
00001'000000 BOTLN:     0
00002'000000 SONLN:     0
00003'000000 TAGLN:     0
00004'000545',ZVL1:     ZVLE1
00005'000023 INC1:      23
00006'000000 FN1SK:     0
00007'000221',RETN:     RETRN
00010'056777 FIN2:      STA     @3,.RETN        ;SAVE RETURN ADR.
00011'031400            LDA     2,0,3   ;GET DATA TB. ADR.
00012'021026            LDA     0,26,2  ;TOP LY. NO.
00013'040765            STA     0,TOPLN
00014'021027            LDA     0,27,2  ;BOT. LY. NO.
00015'040764            STA     0,BOTLN
00016'021020            LDA     0,20,2  ;SONO. LY. NO.
00017'040763            STA     0,SONLN
00020'021021            LDA     0,21,2  ;TARG. LY. NO.
00021'040762            STA     0,TAGLN
00022'020763            LDA     0,INC1
00023'143000            ADD     2,0     ;Z VALUE ADR.
00024'040542            STA     0,ZVLEA
00025'042757            STA     @0,.ZVL1
00026'021033            LDA     0,33,2  ;A+B FLAG
00027'040757            STA     0,FN1SK
00030'020572            LDA     0,.GDTB ;GET ADR. OF GRAD. TB.
00031'024747            LDA     1,TOPLN ;GET TOP LY. NO.
00032'030571            LDA     2,DBINC ;GET DATA BLOCK INCREMENT.
00033'176520            SUBZL   3,3     ;ONE IN AC3
00034'125004            MOV     1,1,SZR ;SKIP IF TOP LY. NO. IS ZERO
00035'166400            SUB     3,1     ;TOP LY. NO. - ONE
00036'135000            MOV     1,3     ;SAVE RESULT
00037'073301            MUL             ;COMPUTE ADR. OF GRAD. TB.
```

```
0002  FIN2
 00040'046564          STA     @1.,GDA1
   00041'046564          STA     @1.,GDA2
 00042'046564          STA     @1.,GDA3
 00043'024736          LDA     1,BOTLN ;GET BOT. LAY. NO.
 00044'121000          MOV     1,0     ;SAVE
 00045'166400          SUB     3,1     ;BOT. LY. NO. - ADJ. TOP LY. NO.
 00046'044561          STA     1,CNTRR ;STORE AS LOOP COUNTER
 00047'030562          LDA     2,FOURQ ;GET FOUR
 00050'112400          SUB     0,2     ;FOUR - BOT. LY. N O
 00051'151005          MOV     2,2,SNR ;SKIP IF BOT. LY. NO. IS NOT FOUR
 00052'014555          DSZ     CNTRR   ;SUB. ONE FROM LOOP COUNTER
 00053'050557          STA     2,BTFRD ;STORE AS BOT. LY. IS 4 FLAG
 00054'030553          LDA     2,CNTRR
 00055'050553          STA     2,TPBTD ;TOP BOT LAYER DIFF. FLAG
 00056'024724          LDA     1,SONLN
 00057'166400          SUB     3,1     ;SONO.  LY. NP. -ADJ. TOP LY. NO
 00060'044553          STA     1,SNCNT
 00061'024722          LDA     1,TAGLN         ;GET TARG. LY. NO.
 00062'166400          SUB     3,1     ;TARG. LY. NO. - ADJ. TOP LY. NO.
 00063'044551          STA     1,TGCNT
 00064'102400          SUB     0,0     ;ZERO IN AC0
 00065'024550          LDA     1,DATCN ;NO. OF DATA LOCATION
 00066'030550          LDA     2,DATPR
 00067'041000 DATLP:   STA     0,0,2   ;INITIALIZE DATA LOOP
 00070'151400          INC     2,2
 00071'125404          INC     1,1,SZR
 00072'000775          JMP     DATLP
 00073'020705          LDA     0,TOPLN ;GET TOP LAYER NO.
 00074'126400          SUB     1,1     ;ZERO IN AC1
 00075'101004          MOV     0,0,SZR ;SKIP IF TOP LY. NO. IS ZERO
 00076'125400          INC     1,1     ;ONE IN AC1
 00077'044540          STA     1,TPFLG ;STORE AS TOP LY. IS ZERO FLAG
 00100'030540          LDA     2,ZMVST ;GET ADR. OF RG. SQRTMTB.
 00101'052542          STA     @2,.RGA1;SET UP ADR'S
 00102'034521          LDA     3,DBINC ;GET DATA BLOCK INCREM.
 00103'173000          ADD     3,2
 00104'052540          STA     @2,.RGA2
 00105'030534          LDA     2,DVTBT ;GET ADR. OF DV. SQRT TB.
 00106'052537          STA     @2,.DVA1;SET UP ADR.'S
 00107'173000          ADD     3,2
 00110'052536          STA     @2,.DVA2
 00111'030531          LDA     2,TMTBT ;GET ADR. OF TM. SQRT TB.
 00112'052535          STA     @2,.TMA1
 00113'173000          ADD     3,2
 00114'052534          STA     @2,.TMA2
 00115'020671 LOOP:    LDA     0,FN1SK;SKIP OVER A AND B CAL. FLAG
 00116'101005          MOV     0,0,SNR
 00117'000407          JMP     ENT11
 00120'014513          DSZ     SNCNT   ;A FLAG
 00121'000402          JMP     .+2
 00122'006527          JSR     @.SNCL  ;DO A PART OF RAY
 00123'014511          DSZ     TGCNT   ;B FLAG
 00124'000402          JMP     .+2
 00125'006525          JSR     @.TGCL  ;DO B PART OF RAY
 00126'020501 ENT11:   LDA     0,CNTRR ;GET LOOP COUNTER
 00127'101234          MOVZR#  0,0,SZR ;SKIP IF COUNTER ONE
 00130'000413          JMP     ENTR1   ;NOT LAST LOOP THRU PROGRAM
 00131'014477          DSZ     TPBTD   ;SKIP IF LY. DIFF. FLAG IS ONE
 00132'000405          JMP     ENTR2   ;TOP AND BOT. LY. NO.'S DIFF. BY > ONE
```

LISTING C13 (Continued)

```
0003  FIN2
 00133'020477          LDA     0,BTFRD ;GET BOT. LY. IS FOUR FLAG
 00134'101004          MOV     0,0,SZR ;SKIP IF FLAG IS ZERO
 00135'000412          JMP     ENTR3
 00136'000420          JMP     ENTR5
 00137'020473 ENTR2:   LDA     0,BTFRD ;GET BOT. LY. IS FOUR FLAG
 00140'101004          MOV     0,0,SZR ;SKIP IF FLAG IS ZERO
 00141'000406          JMP     ENTR3
 00142'000407          JMP     ENTR4
 00143'020474 ENTR1:   LDA     0,TPFLG ;GET TOP LY. IS ZERO FLAG
 00144'101004          MOV     0,0,SZR ;SKIP IF FLAG IS ZERO
 00145'000411          JMP     ENTR5
 00146'000403          JMP     ENTR4
 00147'004525 ENTR3:   JSR     ONEP    ;ADD IN BOT. TURN AROUND RAY
 00150'000414          JMP     ENDRR   ;END OF LOOP
 00151'004503 ENTR4:   JSR     TWOD    ;ADD IN THRU LAYER RAY
 00152'004420          JSR     INCAD   ;UPDATE DATA TB. ADR.'S
 00153'014454          DSZ     CNTRR   ;SKIP IF COMPUT. COMPLETE
 00154'000741          JMP     LOOP    ;LOOP TO NEXT LAYER
 00155'000407          JMP     ENDRR   ;END OF LOOP
 00156'004522 ENTR5:   JSR     ONEN    ;ADD IN TOP TURN AROUND RAY
 00157'004433          JSR     INCGD
 00160'102400          SUB     0,0
 00161'040456          STA     0,TPFLG ;SET FLAG TO ZERO
 00162'014445          DSZ     CNTRR   ;SKIP IF COMPUT. COMPLETE
 00163'000732          JMP     LOOP    ;LOOP TO NEXT LAYER
 00164'006467 ENDRR:   JSR     @.FMUL  ;Z. * TOTAL DERIV.
 00165'000564'         CDV1
 00166'000000 ZVLEA:   0
 00167'000564'         CDV1
 00170'034431          LDA     3,RETRN ;GET RETURN ADR.
 00171'001401          JMP     1,3     ;RETURN
 00172'020431 INCAD:   LDA     0,DBINC ;GET DATA BASE INCREM.
 00173'024465          LDA     1,RGA1  ;SETUP NEXT ADR'.S
 00174'107000          ADD     0,1
 00175'044463          STA     1,RGA1
 00176'107000          ADD     0,1
 00177'044462          STA     1,RGA2
 00200'024464          LDA     1,DVA1
 00201'107000          ADD     0,1
 00202'044462          STA     1,DVA1
 00203'107000          ADD     0,1
 00204'044461          STA     1,DVA2
 00205'024463          LDA     1,TMA1
 00206'107000          ADD     0,1
 00207'044461          STA     1,TMA1
 00210'107000          ADD     0,1
 00211'044460          STA     1,TMA2
 00212'020411 INCGD:   LDA     0,DBINC
 00213'024507          LDA     1,GDA1
 00214'107000          ADD     0,1
 00215'044505          STA     1,GDA1
 00216'044510          STA     1,GDA2
 00217'044513          STA     1,GDA3
 00220'001400          JMP     0,3     ;RETURN
 00221'000000 RETRN:   0
 00222'177777 ,GDTB:   GDTBL
 00223'000003 DBINC:   3
 00224'000322',GDA1:   GDA1
 00225'000326',GDA2:   GDA2
```

LISTING C14 (Continued)

```
0004  FIN2
 00226'000332'.GDAS:  GDAS
 00227'000000 CNTRR:  0
 00230'000000 TPBTD:  0
 00231'000004 FOURQ:  4
 00232'000000 BTFRD:  0
 00233'000000 SNCNT:  0
 00234'000000 TGCNT:  0
 00235'177745 DATCN:  177745          ;- 27
 00236'000561'DATPR:  CRG1
 00237'000000 TPFLG:  0
 00240'177777 ZMVST:  ZMVTB
 00241'177777 DVTBT:  DVTTB
 00242'177777 TMTBT:  TMTTB
 00243'000260'.RGA1:  RGA1
 00244'000261'.RGA2:  RGA2
 00245'000264'.DVA1:  DVA1
 00246'000265'.DVA2:  DVA2
 00247'000270'.TMA1:  TMA1
 00250'000271'.TMA2:  TMA2
 00251'000413'.SNCL:  SNCAL
 00252'000426'.TGCL:  TGCAL
 00253'177777 .FMUL:  FFML
 00254'054516 TWOD:   STA     3.RETUN ;SAVE RETURN ADR.
 00255'102400         SUB     0.0     ;ZERO IN AC0
 00256'040515         STA     0.FLAG1 ;SET FLAG TO ZERO
 00257'006515         JSR     @.FSUB  ;RG. SQRT1 - RG. SQRT2
 00260'000000 RGA1:   0
 00261'000000 RGA2:   0
 00262'000375'        TEMA1
 00263'006511         JSR     @.FSUB  ;DV. SQRT1 - DV. SQRT2
 00264'000000 DVA1:   0
 00265'000000 DVA2:   0               ;ADR. OF BOT. LY. DV. SQRT.
 00266'000400'        TEMA2           ;ADR. OF RESULT
 00267'006505         JSR     @.FSUB  ;TM. SQRT1 - TM. SQRT2
 00270'000000 TMA1:   0               ;ADR. OF TOPLY. TM. SQRT
 00271'000000 TMA2:   0               ;ADR. OF BOT. LY. TM. SQRT
 00272'000403'        TEMA3           ;ADR. OF RESULT
 00273'000417         JMP     ENTR6   ;FIX ADR.'S FOR FPDV SUBROUTINE
 00274'054476 ONEP:   STA     3.RETUN ;SAVE RETURN
 00275'102400         SUB     0.0     ;ZERO IN AC0
 00276'040475         STA     0.FLAG1 ;INITIALIZE FLAG ONE
 00277'000404         JMP     ENTR7   ;FIX ADR.'S MFOR FPDV SUBROUTINE
 00300'054472 ONEN:   STA     3.RETUN ;SAVE RETURN ADR.
 00301'102520         SUBZL   0.0     ;ONE IN AC0
 00302'040471         STA     0.FLAG1 ;INITIALIZE FLAG ONE
 00303'020755 ENTR7:  LDA     0.RGA1  ;STORE ADR.'S OF SQRT
 00304'040415         STA     0.FXAD1 ;TABLES IN FPDV SUBROUTINE
 00305'020757         LDA     0.DVA1
 00306'040417         STA     0.FXAD2
 00307'020761         LDA     0.TMA1
 00310'040421         STA     0.FXAD3
 00311'000407         JMP     ARND1   ;JUMP AROUND NEXT PART
 00312'020474 ENTR6:  LDA     0.,TEM1 ;STORE ADR.'S OF SQRT
 00313'040406         STA     0.FXAD1 ;DIFFERENCES IN FPDV SUBROUTINE
 00314'020473         LDA     0.,TEM2
 00315'040410         STA     0.FXAD2
 00316'020472         LDA     0.,TEM3
 00317'040412         STA     0.FXAD3
 00320'006471 ARND1:  JSR     @.FDIV  ;(ABOVE RG. RESULT)/GRAD.
```

LISTING C14 (Continued)

```
0005  FIN2
 00321'000375'FXAD1:  TEMA1           ;ADR. OF RG. RESULT
 00322'000000 GDA1:   0               ;ADR. OF GRAD.
 00323'000375'        TEMA1           ;ADR. OF RESULT
 00324'006465         JSR     @.FDIV  ;(ABOVE DY. RESULT)/GRAD.
 00325'000400'FXAD2:  TEMA2           ;ADR. OF DY. RESULT
 00326'000000 GDA2:   0               ;ADR. OF GRAD.
 00327'000400'        TEMA2           ;ADR.  OF RESULT
 00330'006461         JSR     @.FDIV  ;(ABOVE TM. DY. RESULT)/GRAD.
 00331'000403'FXAD3:  TEMA3           ;ADR. OF TM. DY. RESULT
 00332'000000 GDA3:   0               ;ADR. OF GRAD.
 00333'000403'        TEMA3           ;ADR. OF RESULT
 00334'020437         LDA     0.FLAG1 ;GET FLAG ONE
 00335'101005         MOV     0,0.SNR ;SKIP IF FLAG IS ONE
 00336'000416         JMP     ENTR8   ;ADD IN LAYER RESULTS
 00337'006435         JSR     @.FSUB  ;HC. RG. SUB TOTAL - LY. RG.
 00340'000561'        CRG1            ;ADR. OF HALF CYC. RANGE
 00341'000375'        TEMA1           ;ADR. OF LY. RG.
 00342'000561'        CRG1            ;ADR. OF HALF CYC. RANGE
 00343'006431         JSR     @.FSUB  ;HC. DY. SUB TOTAL - LY DERIV.
 00344'000564'        CDV1            ;ADR. OF HALF CYC. DERIV.
 00345'000400'        TEMA2           ;ADR. OF LY.DERIV
 00346'000564'        CDV1            ;ADR. OF HALF CYC. DERIV
 00347'006425         JSR     @.FSUB  ;HC. TM. DY. SUB TOTLA - LY. TM. DY.
 00350'000567'        CTM1            ;ADR. OF HALF CYC. TM. DY.
 00351'000403'        TEMA3           ;ADR. OF LY. TM. DY.
 00352'000567'        CTM1            ;ADR. OF HALF CYC. TM. DY.
 00353'000415         JMP     ENTR9   ;END FIN2
 00354'006436 ENTR8:  JSR     @.FADD  ;HC. RG. SUB TOTAL + LY. RG.
 00355'000561'        CRG1            ;ADR. OF HALF CYC. RANGE
 00356'000375'        TEMA1           ;ADR. OF LY. RG.
 00357'000561'        CRG1            ;ADR. OF HALF CYC. RANGE
 00360'006432         JSR     @.FADD  ;HC. DY. SUB TOTAL + LY. DY.
 00361'000564'        CDV1            ;ADR. OF HALF CYC. DERIV.
 00362'000400'        TEMA2           ;ADR. OF LY. DERIV.
 00363'000564'        CDV1            ;ADR. OF HALF CYC. DERIV.
 00364'006426         JSR     @.FADD  ;HC. TM. DY. SUB TOTAL + LY. TM. DY.
 00365'000567'        CTM1            ;ADR. OF HALF CYC. TM. DY.
 00366'000403'        TEMA3           ;ADR. OF LY. TM. DY.
 00367'000567'        CTM1            ;ADR. OF HALF CY. TM. DY.
 00370'054402 ENTR9:  LDA     3.RETUN ;GET RETURN ADR.
 00371'001400         JMP     0.3     ;RETURN
 00372'000000 RETUN:  0
 00373'000000 FLAG1:  0
 00374'177777 .FSUB:  FFSB
 00375'000000 TEMA1:  0
 00376'000000         0
 00377'000000         0
 00400'000000 TEMA2:  0
 00401'000000         0
 00402'000000         0
 00403'000000 TEMA3:  0
 00404'000000         0
 00405'000000         0
 00406'000375'.TEM1:  TEMA1
 00407'000400'.TEM2:  TEMA2
 00410'000403'.TEM3:  TEMA3
 00411'177777 .FDIV:  FFDV
 00412'177777 .FADD:  FFAD
 00413'054426 SNCAL:  STA     3.RETR1 ;SAVE RETURN ADR.
```

LISTING C14 (Continued)

```
0006  FIN2
 00414'004426          JSR     TSCAL   ;DO CALCULATION FOR A
 00415'177777          SNRG1
 00416'177777          SNDV1
 00417'177777          SNTM1
 00420'000002'         SONLN
 00421'000572'         ARG1
 00422'000575'         ADV1
 00423'000600'         ATM1
 00424'034415          LDA     3,RETR1 ;GET RETURN ADR.
 00425'001400          JMP     0,3     ;RETURN
 00426'054413 TGCAL:   STA     3,RETR1 ;SAVE RETURN ADR.
 00427'004413          JSR     TSCAL   ;DO CALCULATION FOR B
 00430'177777          TGRG1
 00431'177777          TGDV1
 00432'177777          TGTM1
 00433'000003'         TAGLN
 00434'000605'         BRG1
 00435'000606'         BDV1
 00436'000611'         BTM1
 00437'034402          LDA     3,RETR1 ;GET RETURN ADR.
 00440'001400          JMP     0,3     ;RETURN
 00441'000000 RETR1:   0
 00442'054513 TSCAL:   STA     3,RETR2 ;SAVE RETURN ADR.
 00443'021400          LDA     0,0,3   ;SET UP ADR IN SUBROUTINE
 00444'040441          STA     0,RGA4
 00445'021401          LDA     0,1,3
 00446'040443          STA     0,DVA4
 00447'021402          LDA     0,2,3
 00450'040445          STA     0,TMA4
 00451'021404          LDA     0,4,3
 00452'040464          STA     0,RGA5
 00453'021405          LDA     0,5,3
 00454'040466          STA     0,DVA5
 00455'040467          STA     0,DVA6
 00456'040470          STA     0,DVA7
 00457'021406          LDA     0,6,3
 00460'040472          STA     0,TMA5
 00461'020641          LDA     0,GDA1
 00462'040457          STA     0,GDA4
 00463'040442          STA     0,GDA5
 00464'040445          STA     0,GDA6
 00465'023403          LDA     @0,3,3  ;GET OBJ. LY. NO.
 00466'026470          LDA     @1,,TPNM;GET TOP.LY. NO.
 00467'106404          SUB     0,1,SZR ;SKIP IF TWO LY. EQUAL
 00470'000405          JMP     TWOXD
 00471'020466 ONEXN:   LDA     0,,ZER1 ;GET ZERO DATA ADR.
 00472'105000          MOV     0,1
 00473'111000          MOV     0,2
 00474'000404          JMP     ENT10
 00475'022522 TWOXD:   LDA     @0,RGA1A
 00476'026522          LDA     @1,DVA1A
 00477'032522          LDA     @2,TMA1A
 00500'040404 ENT10:   STA     0,RGA3  ;SET UP ADR.'S
 00501'044407          STA     1,DVA3
 00502'050412          STA     2,TMA3
 00503'006671          JSR     @.FSUB  ;RG1 - RG0B
 00504'000000 RGA3:    0
 00505'000000 RGA4:    0
 00506'000375'         TEMA1
```

LISTING C14 (Continued)

```
0007  FIN2
  00507'006665          JSR     @.FSUB  ;DV1 - DVOB
  00510'000000 DVA3;    0
  00511'000000 DVA4;    0
  00512'000400'         TEMA2
  00513'006661          JSR     @.FSUB  ;TM1 - TMOB
  00514'000000 TMA3;    0
  00515'000000 TMA4;    0
  00516'000403'         TEMA3
  00517'006672          JSR     @.FDIV  ;(DELTA RG.)/ GRAD.
  00520'000375'         TEMA1
  00521'000000 GDA4;    0
  00522'000375'         TEMA1
  00523'006666          JSR     @.FDIV  ;(DELTA DV.)/ GRAD.
  00524'000400'         TEMA2
  00525'000000 GDA5;    0
  00526'000400'         TEMA2
  00527'006662          JSR     @.FDIV  ;(DELTA TM)/ GRAD.
  00530'000403'         TEMA3
  00531'000000 GDA6;    0
  00532'000403'         TEMA3
  00533'006657          JSR     @.FADD  ;TOTAL UP RNG.
  00534'000375'         TEMA1
  00535'000561'         CRG1
  00536'000000 RGA5;    0
  00537'006653          JSR     @.FADD  ;TOTAL UP DV.
  00540'000400'         TEMA2
  00541'000564'         CDV1
  00542'000000 DVA5;    0
  00543'006415          JSR     @.FMPY  ;Z TIMES DV. CAL.
  00544'000000 DVA6;    0
  00545'000000 ZVLE1;   0
  00546'000000 DVA7;    0
  00547'006643          JSR     @.FADD  ;TOTAL UP TM.
  00550'000403'         TEMA3
  00551'000567'         CTM1
  00552'000000 TMA5;    0
  00553'034402          LDA     3,RETR2 ;GET RETURN ADR.
  00554'001407          JMP     7,3     ;RETURN
  00555'000000 RETR2;   0
  00556'000000'.TPNM;   TOPLN
  00557'000614'.ZER1;   ZERO1
  00560'000253'.FMPY;   FFML
  00561'000000 CRG1;    0
  00562'000000          0
  00563'000000          0
  00564'000000 CDV1;    0
  00565'000000          0
  00566'000000          0
  00567'000000 CTM1;    0
  00570'000000          0
  00571'000000          0
  00572'000000 ARG1;    0
  00573'000000          0
  00574'000000          0
  00575'000000 ADV1;    0
  00576'000000          0
  00577'000000          0
  00600'000000 ATM1;    0
  00601'000000          0
```

LISTING C14 (Continued)

```
0008  FIN2
  00602'000000            0
  00603'000000 BRG1:      0
  00604'000000            0
  00605'000000            0
  00606'000000 BDV1:      0
  00607'000000            0
  00610'000000            0
  00611'000000 BTM1:      0
  00512'000000            0
  00613'000000            0
  00614'040000 ZERO1:     040000
  00615'000000            0
  00616'000000            0
  00617'000260'RGA1A:     RGA1
  00620'000264'DVA1A:     DVA1
  00621'000270'TMA1A:     TMA1
                          .END
```

LISTING C14 (Continued)

FQ2 SUBROUTINE

1. The FQ2 subroutine combines the A, B, and C parts of the ray path to form the total horizontal range, total derivative, and total time delay for the path. This subroutine is one of the three main computational routines.

2. NRMA

3.
```
          JSR@ .FQ2
          BGDAT
     .
     .
     .
    .FQ2:   FQ2
```

4. FPMP

5. DIRMD, NUMCY, ARG1, ADV1, ATM1, BRG1, BDV1, BTM1, CRG1, CDV1, and CTM1.

6. TRG1, TDV1, and TTM1.

7. See Figure C15.

8. See Listing C15.

9. The following algorithm is computed by this subroutine:

DIRMD	NUMCY (N)	C Value
1	EVEN NO.	$N \cdot C + A + B$
0	EVEN NO.	$(N+2) \cdot C - A - B$
0	ODD NO.	$(N+1) \cdot C - A + B$
1	ODD NO.	$(N+1) \cdot C + A - B$

if N = -1 then C = A - B or B - A based on which of the two calculations gives a positive result for the horizontal range.

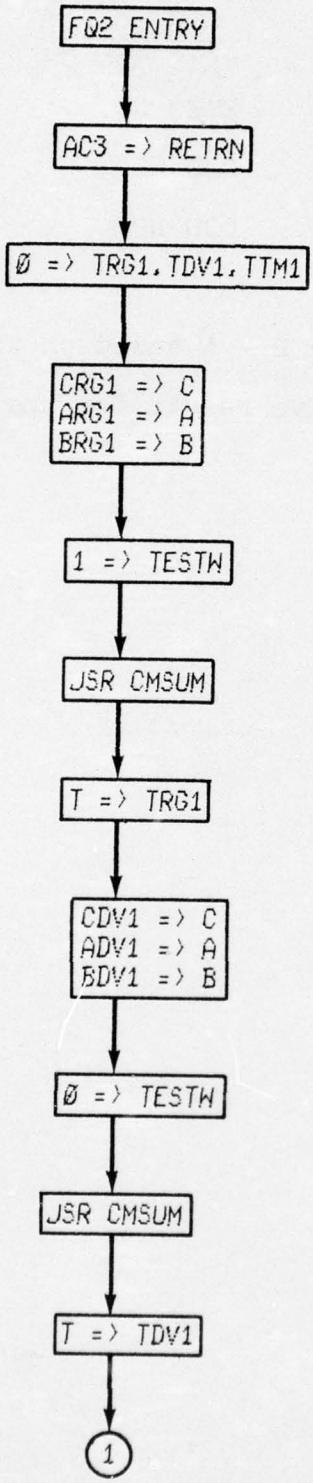

FQ2 ENTRY
AC3 => RETRN
Ø => TRG1, TDV1, TTM1
CRG1 => C
ARG1 => A
BRG1 => B
1 => TESTW
JSR CMSUM
T => TRG1
CDV1 => C
ADV1 => A
BDV1 => B
Ø => TESTW
JSR CMSUM
T => TDV1
1

FIG. C15

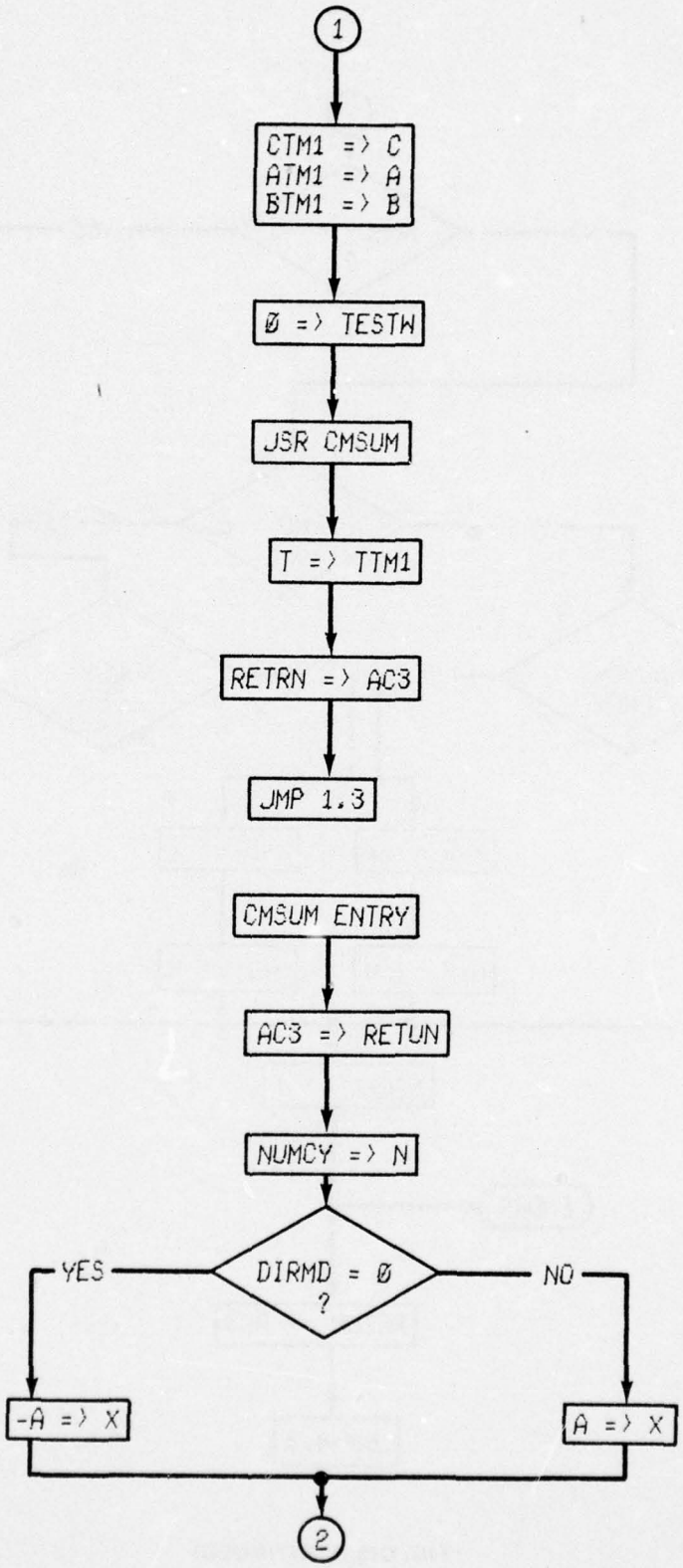


FIG. C15 (CONTINUED)

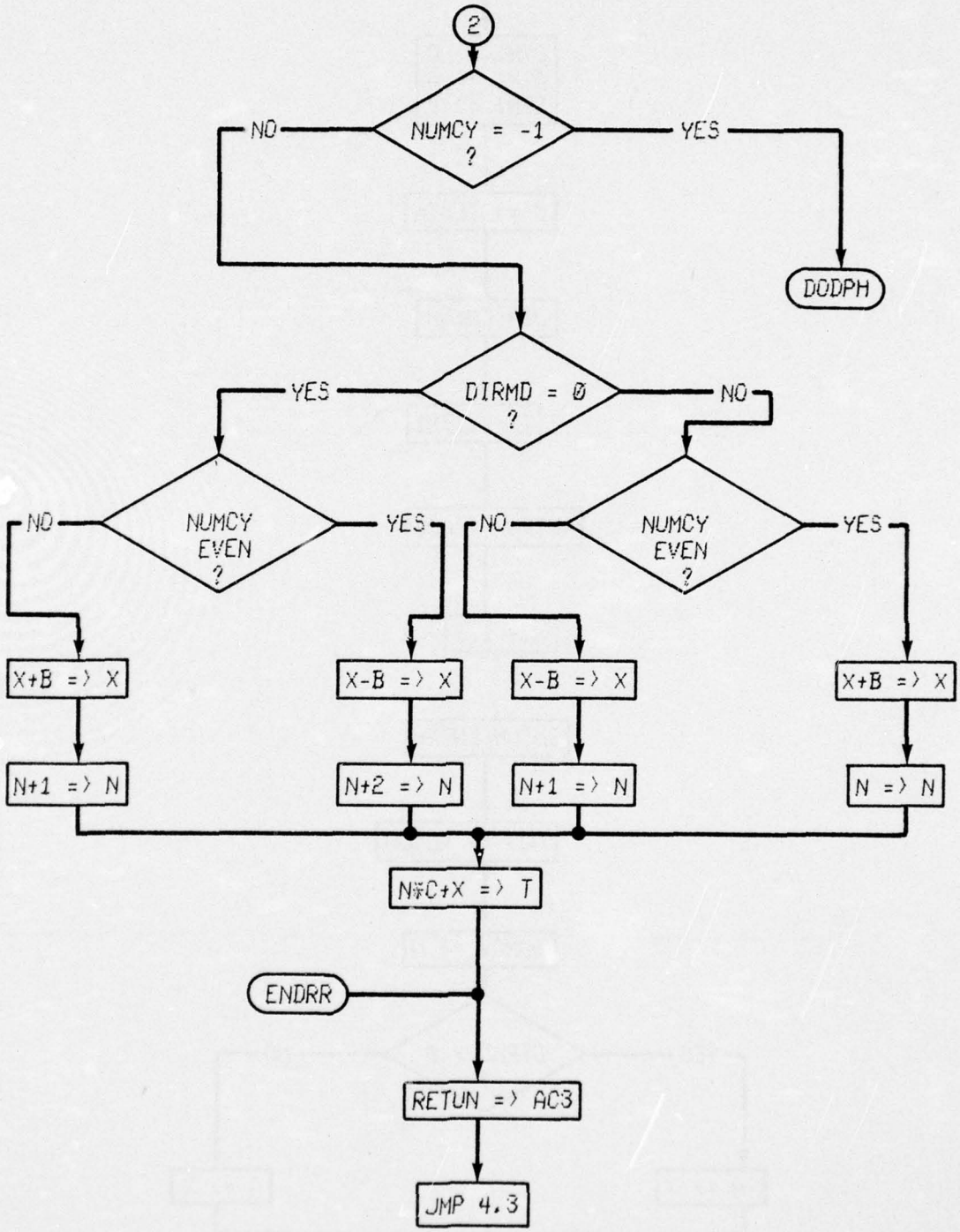


FIG. C15 (CONTINUED)

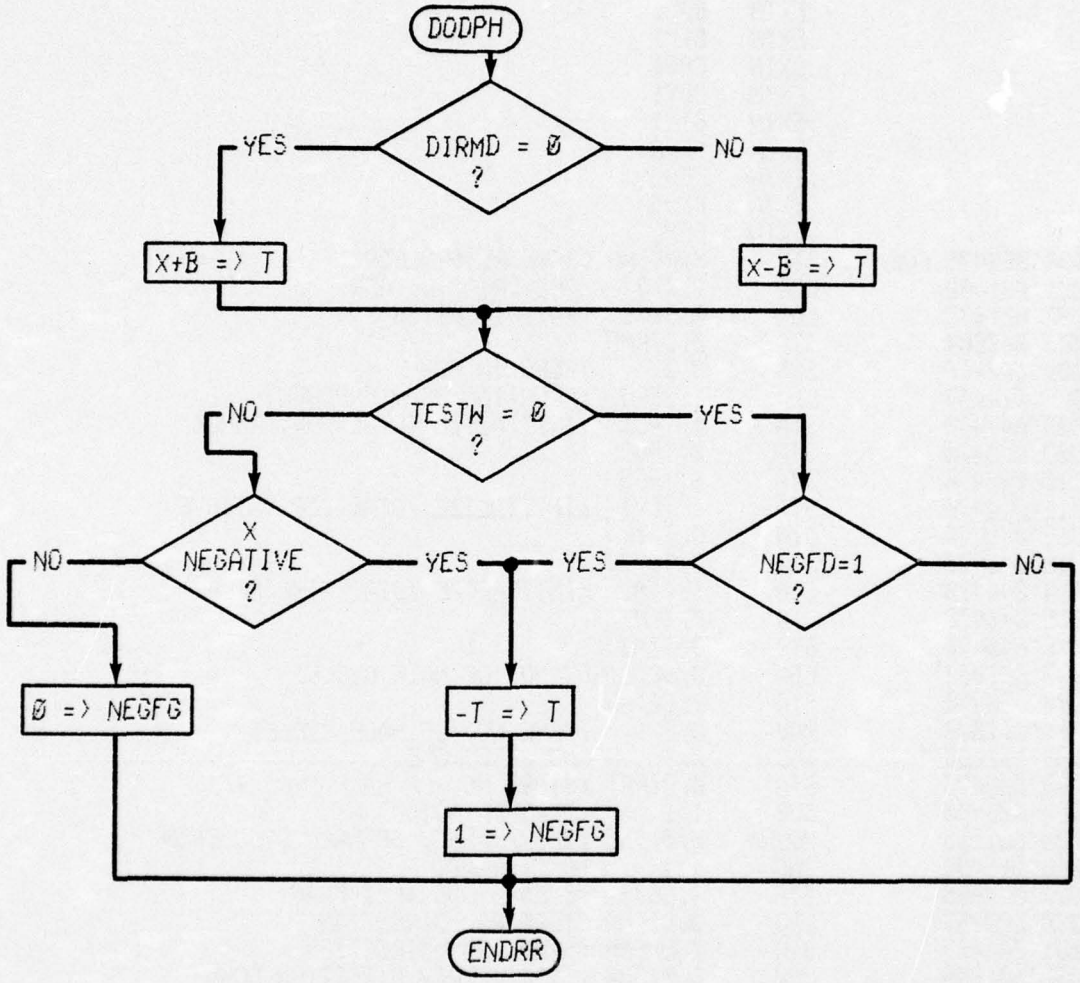


FIG. C15 (CONTINUED)

```
                        .NREL
                        .TITL   FQ2     ;3/15/74
        000010          .RDX    8
                        .ENT    FQ2
                        .ENT    TRG1
                        .ENT    TDV1
                        .ENT    TTM1
                        .EXTN   ARG1
                        .EXTN   ADV1
                        .EXTN   ATM1
                        .EXTN   BRG1
                        .EXTN   BDV1
                        .EXTN   BTM1
                        .EXTN   CRG1
                        .EXTN   CDV1
                        .EXTN   CTM1
                        .EXTN   FFLD
                        .EXTN   FFAD
                        .EXTN   FFSB
                        .EXTN   FFML
00000'054475 FQ2:       STA     3,RETRN ;SAVE RE $RN ADR.
00001'031400            LDA     2,0,3   ;GET DATA TB. ADR.
00002'021030            LDA     0,30,2  ;RAY DIRECTION
00003'040504            STA     0,DIRMD
00004'102400            SUB     0,0     ;ZERO IN AC0
00005'024467            LDA     1,ZERO  ;FLOATING ZERO EXPONENT
00006'044470            STA     1,TRG1  ;INITIALIZE TOTAL HOR. RANGE
00007'040470            STA     0,TRG2
00010'040470            STA     0,TRG3
00011'044470            STA     1,TDV1  ;INITIALIZE TOTAL DERIVATIOVE
00012'040470            STA     0,TDV2
00013'040470            STA     0,TDV3
00014'044470            STA     1,TTM1  ;INITIALIZE TOTAL TIME DELAY
00015'040470            STA     0,TTM2
00016'040470            STA     0,TTM3
00017'021032            LDA     0,32,2;GET NO. OF HALF CYCLES
00020'050470            STA     2,DATAD
00021'111000            MOV     0,2     ;SAVE NO. OF HALF CYCLES
00022'101400            INC     0,0     ;NO. PLUS ONE
00023'040473            STA     0,DIRPT ;STORE NO. OF HALF CYC. + 1
00024'126400            SUB     1,1     ;ZERO IN AC1
00025'101213            MOVR#   0,0,SNC ;SKIP IF NO. OF HALF CYC. EVEN
00026'125400            INC     1,1     ;ONE IN AC1
00027'044466            STA     1,EOTST ;EVEN - ODD TEST FLAG
00030'020457            LDA     0,DIRMD;STORE RAY DIRECTION
00031'040463            STA     0,UPDNR ;STORE RAY DIRECTION
00032'101005            MOV     0,0,SNR ;SKIP IF RAY DIRECTION DOWN
00033'000402            JMP     ENTR1   ;DO UP RAY AT SONOBUOY
00034'000405            JMP     ENTR2   ;DO DOWN RAY AT SONOBUOY
00035'151400 ENTR1:     INC     2,2     ;INCREMENT NO. OF HALF CYC.
00036'125005            MOV     1,1,SNR ;SKIP IF EOTST IS ONE
00037'151400            INC     2,2     ;INCREMENT NO. OF HALF CYCLES
00040'000403            JMP     ENTR3   ;FLOAT NO. OF HALF CYCLES
00041'125004 ENTR2:     MOV     1,1,SZR ;SKIP IF EOTST IS ZERO
00042'151400            INC     2,2     ;INCREMENT NO. OF HALF CYCLES
00043'050447 ENTR3:     STA     2,NOCYL ;STORE NO. OF HALF CYCLES
00044'006447            JSR     @.FFLD  ;FLOAT NO. OF HALF CYCLES
00045'000111'           NOCYH           ;ADR. OF ALTERED NO. OF HALF CYC.
```

```
0002  FQ2
 00046'000000          0                   ;B0 DOUBLE PRECISION
 00047'000233'         NOMC1               ;ADR. OF FLOATING PT. RESULT
 00050'102520          SUBZL   0,0         ;ONE IN AC0
 00051'004446          JSR     CMSUM       ;ASSEMBLE TOTAL HOR. RANGE
 00052'177777          ARG1                ;ADR. OF A HOR. RANGE
 00053'177777          BRG1                ;ADR. OF B HOR. RANGE
 00054'177777          CRG1                ;ADR. OF HALF CYC. HOR. RANGE
 00055'000076'         TRG1                ;ADR. OF TOTAL HOR. RANGE
 00056'102400          SUB     0,0         ;ZERO IN AC0
 00057'004440          JSR     CMSUM       ;ASSEMBLE TOTAL DERIVATIVE
 00060'177777          ADV1                ;ADR. OF A DERIVATIVE
 00061'177777          BDV1                ;ADR. OF B DERIVATIVE
 00062'177777          CDV1                ;ADR. OF HALF CYC. DERIVATIVE
 00063'000101'         TDV1                ;ADR. OF TOTAL DERIVATIVE
 00064'102400          SUB     0,0         ;ZERO IN DERIVATIVE
 00065'004432          JSR     CMSUM       ;ASSEMBLE TOTAL TIME DELAY
 00066'177777          ATM1                ;ADR. OF A TIME DELAY
 00067'177777          BTM1                ;ADR. OF B TIME DELAY
 00070'177777          CTM1                ;ADR. OF HALF CYC. TIME DELAY
 00071'000104'         TTM1                ;ADR. OF TOTAL TIME DELAY
 00072'034403          LDA     3,RETRN     ;GET RETURN ADR.
 00073'001401          JMP     1,3         ;RETURN
 00074'040000 ZERO;    040000
 00075'000000 RETRN:   0
 00076'000000 TRG1:    0
 00077'000000 TRG2;    0
 00100'000000 TRG3:    0
 00101'000000 TDV1:    0
 00102'000000 TDV2:    0
 00103'000000 TDV3:    0
 00104'000000 TTM1:    0
 00105'000000 TTM2;    0
 00106'000000 TTM3;    0
 00107'000000 DIRMD;   0
 00110'000000 DATAD;   0
 00111'000000 NOCYH;   0
 00112'000000 NOCYL;   0
 00113'177777 .FFLD;   FFLD
 00114'000000 UPDNR:   0
 00115'000000 EOTST;   0
 00116'000000 DIRPT:   0
 00117'054507 CMSUM:   STA     3,RETUN     ;SAVE RETURN ADR.
 00120'040507          STA     0,TESTW     ;STORE TEST ADR.
 00121'021400          LDA     0,0,3       ;GET A ADR.
 00122'040435          STA     0,AP1       ;STORE A ADR.
 00123'040441          STA     0,AP2
 00124'021401          LDA     0,1,3       ;GET B ADR.
 00125'040460          STA     0,BP1       ;ST_RE B ADR.
 00126'040464          STA     0,BP2
 00127'040517          STA     0,BP3
 00130'040523          STA     0,BP4
 00131'021402          LDA     0,2,3       ;GET C ADR.
 00132'040464          STA     0,CP1       ;STORE C ADR.
 00133'021403          LDA     0,3,3       ;GET TOTAL ADR.
 00134'040422          STA     0,TP1
 00135'040423          STA     0,TP2
 00136'040425          STA     0,TP3
 00137'040426          STA     0,TP4
 00140'040444          STA     0,TP5
```

LISTING C15 (Continued)

```
0003  FQ2
 00141'040445          STA     0,TP6
 00142'040447          STA     0,TP7
 00143'040450          STA     0,TP8
 00144'040455          STA     0,TP9
 00145'040456          STA     0,TP10
 00146'040477          STA     0,TP11
 00147'040500          STA     0,TP12
 00150'040502          STA     0,TP13
 00151'040503          STA     0,TP14
 00152'030742          LDA     2,UPDNR ;GET UP-DN, FLAG
 00153'151005          MOV     2,2,SNR ;SKIP IF FLAG ZERO
 00154'000406          JMP     ENTR4   ;JUMP AROUND FPAD
 00155'006454          JSR     @,FADD  ;TOTAL PLUS A
 00156'000000 TP1;     0               ;ADR, OF TOTAL
 00157'000000 AP1;     0               ;ADR, OF A
 00160'000000 TP2;     0               ;ADR, OF TOTAL
 00161'000405          JMP     ENTR5   ;JUMP AROUND FPSB
 00162'006450 ENTR4;   JSR     @,FSUB  ;TOTAL MINUS A
 00163'000000 TP3:     0               ;ADR, OF TOTAL
 00164'000000 AP2:     0               ;ADR, OF A
 00165'000000 TP4;     0               ;ADR, OF TOTAL
 00166'034730 ENTR5;   LDA     3,DIRPT ;GET NO, OF HALF CYC, + 1
 00167'175005          MOV     3,3,SNR ;SKIP IF RAY IS NOT - 1
 00170'000451          JMP     DODPH   ;DO - 1 RAY TYPE
 00171'030723          LDA     2,UPDNR ;GET UP-DN, FLAG
 00172'034723          LDA     3,EOTST ;GET EVEN-ODD TEST FLAG
 00173'151005          MOV     2,2,SNR ;SKIP IF RAY DOWN
 00174'000402          JMP     ENTR6   ;DO UP RAY
 00175'000404          JMP     ENTR7   ;DO DOWN RAY
 00176'175004 ENTR6;   MOV     3,3,SZR ;SKIP IF RAY EVEN
 00177'000404          JMP     ENTR8   ;DO ODD RAY
 00200'000410          JMP     ENT10   ;DO EVEN RAY
 00201'175004 ENTR7;   MOV     3,3,SZR ;SKIP IF RAY EVEN
 00202'000406          JMP     ENT10   ;DO ODD RAY
 00203'006426 ENTR8;   JSR     @,FADD  ;TOTAL PLUS B
 00204'000000 TP5;     0               ;ADR, OF TOTAL
 00205'000000 BP1;     0               ;ADR, OF B
 00206'000000 TP6;     0               ;ADR, OF TOTAL
 00207'000405          JMP     ENTR9   ;JUMP AROUND FPSB
 00210'006422 ENT10;   JSR     @,FSUB  ;TOTAL MINUS B
 00211'000000 TP7;     0               ;ADR, OF TOTAL
 00212'000000 BP2;     0               ;ADR, OF B
 00213'000000 TP8;     0               ;ADR, OF TOTAL
 00214'006414 ENTR9;   JSR     @,FMUL  ;ALTERED NO, OF HALF CYC, * C
 00215'000233'         NOMC1           ;ADR, OF ALTERED NO, OF HALF CYC,
 00216'000000 CP1;     0               ;ADR, OF C
 00217'000236'         TEMA1           ;ADR, OF RESULT
 00220'006411          JSR     @,FADD  ;TOTAL PLUS SUM OF C PARTS
 00221'000000 TP9;     0               ;ADR, OF TOTAL
 00222'000236'         TEMA1           ;ADR, OF SUM OF C PARTS
 00223'000000 TP10;    0               ;ADR, OF TOTAL
 00224'034402 ENDRR;   LDA     3,RETUN ;GET RETURN ADR,
 00225'001404          JMP     4,3     ;RETURN
 00226'000000 RETUN;   0
 00227'000000 TESTW;   0
 00230'177777 ,FMUL;   FFML
 00231'177777 ,FADD;   FFAD
 00232'177777 ,FSUB;   FFSB
 00233'000000 NOMC1;   0
```

LISTING C15 (Continued)

```
0004  FQ2
  00234'000000 NOMC2:  0
  00235'000000 NOMC3:  0
  00236'000000 TEMA1:  0
  00237'000000 TEMA2:  0
  00240'000000 TEMA3:  0
  00241'034653 DODPH:  LDA     3,UPDNR ;GET UP-DN. FLAG
  00242'175005         MOV     3,3,SNR ;SKIP IF RAY DOWN
  00243'000406         JMP     ENT11   ;DO UP RAY
  00244'006766         JSR     @.FSUB  ;TOTAL MINUS B
  00245'000000 TP11:   0               ;ADR. OF TOTAL
  00246'000000 BP3:    0               ;ADR. OF B
  00247'000000 TP12:   0               ;ADR. OF TOTAL
  00250'000405         JMP     ENT12   ;JUMP AROUND FPAD
  00251'006760 ENT11:  JSR     @.FADD  ;TOTAL PLUS B
  00252'000000 TP13:   0               ;ADR. OF TOTAL
  00253'000000 BP4:    0               ;ADR. OF B
  00254'000000 TP14:   0               ;ADR. OF TOTAL
  00255'030752 ENT12:  LDA     2,TESTW ;GET TEST FLAG
  00256'151004         MOV     2,2,SZR ;DO DERIV. OR TIME DELAY
  00257'000402         JMP     ENT13   ;DO TOTAL HOR. RANGE
  00260'000421         JMP     ENT14   ;JUMP AROUND TOT. HOR. RNG.
  00261'152400 ENT13:  SUB     2,2     ;ZERO IN AC2
  00262'034772         LDA     3,TP14  ;GET ADR. OF TOT. HOR. RNG.
  00263'021401         LDA     0,1,3   ;GET TOTAL HOR. RNG.
  00264'101113         MOVL#   0,0,SNC ;SKIP IF NEGATIVE
  00265'000412         JMP     ENT15   ;JUMP AROUND NEGATE
  00266'034766 ENT16:  LDA     3,TP14  ;GET ADR. OF TOTAL
  00267'021401         LDA     0,1,3   ;GET TOTAL
  00270'025402         LDA     1,2,3
  00271'124404         NEG     1,1,SZR ;NEGATE TOTAL
  00272'100001         COM     0,0,SKP
  00273'100400         NEG     0,0
  00274'041401         STA     0,1,3   ;STORE TOTAL
  00275'045402         STA     1,2,3
  00276'152520         SUBZL   2,2     ;ONE IN AC2
  00277'050406 ENT15:  STA     2,NEGFG ;STORE NEGATE FLAG
  00300'000724         JMP     ENDRR   ;JMP TO END
  00301'014404 ENT14:  DSZ     NEGFG   ;SKIP IF NEGATE FLAG ONE
  00302'000722         JMP     ENDRR   ;JMP TO END
  00303'000763         JMP     ENT16   ;NEGATE RESULTS
  00304'000000 DUDEC:  0
  00305'000000 NEGFG:  0
                       .END
```

LISTING C15 (Continued)

CPGN SUBROUTINE

1. The CPGN subroutine computes the propagation voltage gain and angle of arrival of a ray path at the sonobuoy. A bottom loss function is also included in the gain calculation.

2. NR1A2

3.
```
        JSR@ .CPGN
        BG. AT
        .
        .
        .
.CPGN:  CPGN
```

4. FPMP

5. LYVEL, TRC1, FDV1, HRRH1, SVLA, TGSQ1, SNSQ1, NUMCY, and ZVAL1

6. GAIN1, ANAR1, and BTAN1

7. See Figure C16.

8. See Listing C16.

9. a) The sine of the angle of arrival of the ray path at the sonobuoy is computed instead of the angle itself. This is also true for the angle that the ray path makes with the bottom. Also all angles are measured from the vertical axis.

   b) The bottom loss function is computed using the following algorithm.

$$BL = A + B \cdot \sin(\theta_B)$$

where $A = .3162$

$B = .6838$

θ_B = angle ray makes with the bottom measured from the vertical.

This computation yields a -10 dB loss at an angle of 0 degrees and no loss at 90 degrees. The total propagation loss is then computed as follows:

$$GAIN1 = RPL \cdot (BL)^{NB}$$

GAIN1 = Total propagation gain

RPL = Propagation gain due to the ray trace

BL = Bottom loss

NB = Number of bottom bounces

c) The sine of the angle that the ray makes with the vertical at any point along the ray is simply equal to the sound velocity at the point divided by the value of z for the ray.

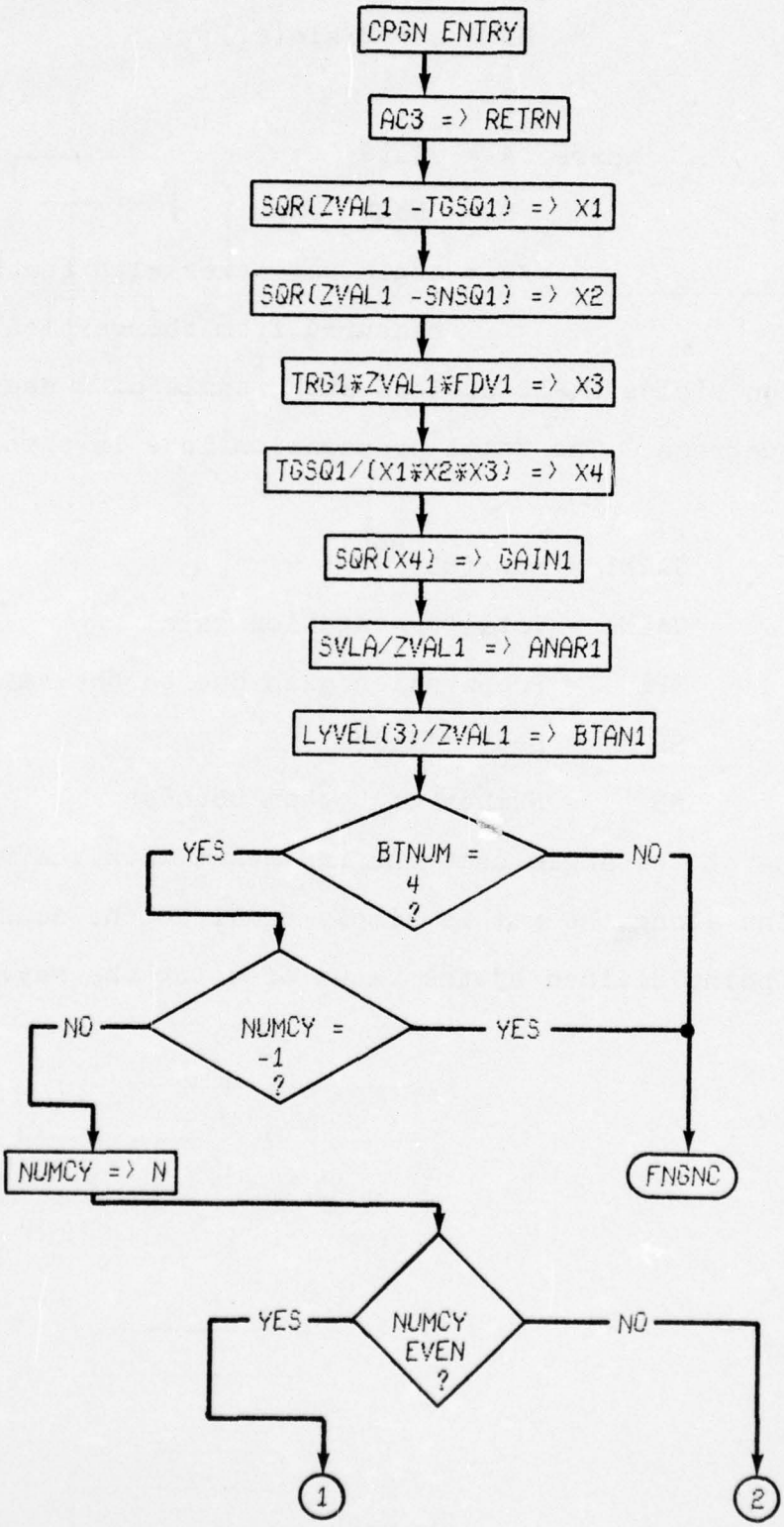

CPGN ENTRY
AC3 => RETRN
SQR(ZVAL1 -TGSQ1) => X1
SQR(ZVAL1 -SNSQ1) => X2
TRG1*ZVAL1*FDV1 => X3
TGSQ1/(X1*X2*X3) => X4
SQR(X4) => GAIN1
SVLA/ZVAL1 => ANAR1
LYVEL(3)/ZVAL1 => BTAN1
BTNUM = 4 ?
YES
NO
NUMCY = -1 ?
NO
YES
NUMCY => N
FNGNC
NUMCY EVEN ?
YES
NO
1
2

FIG. C16

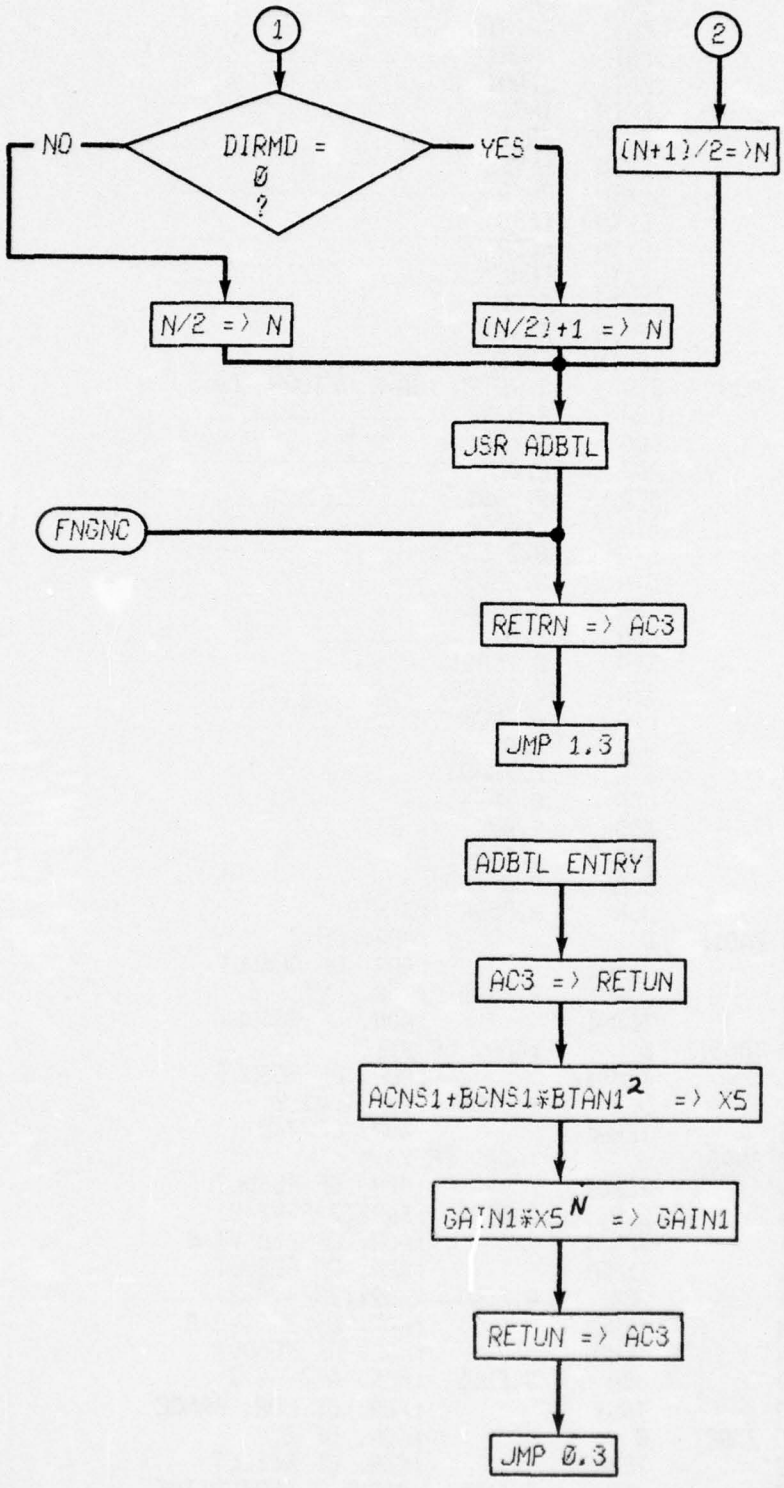
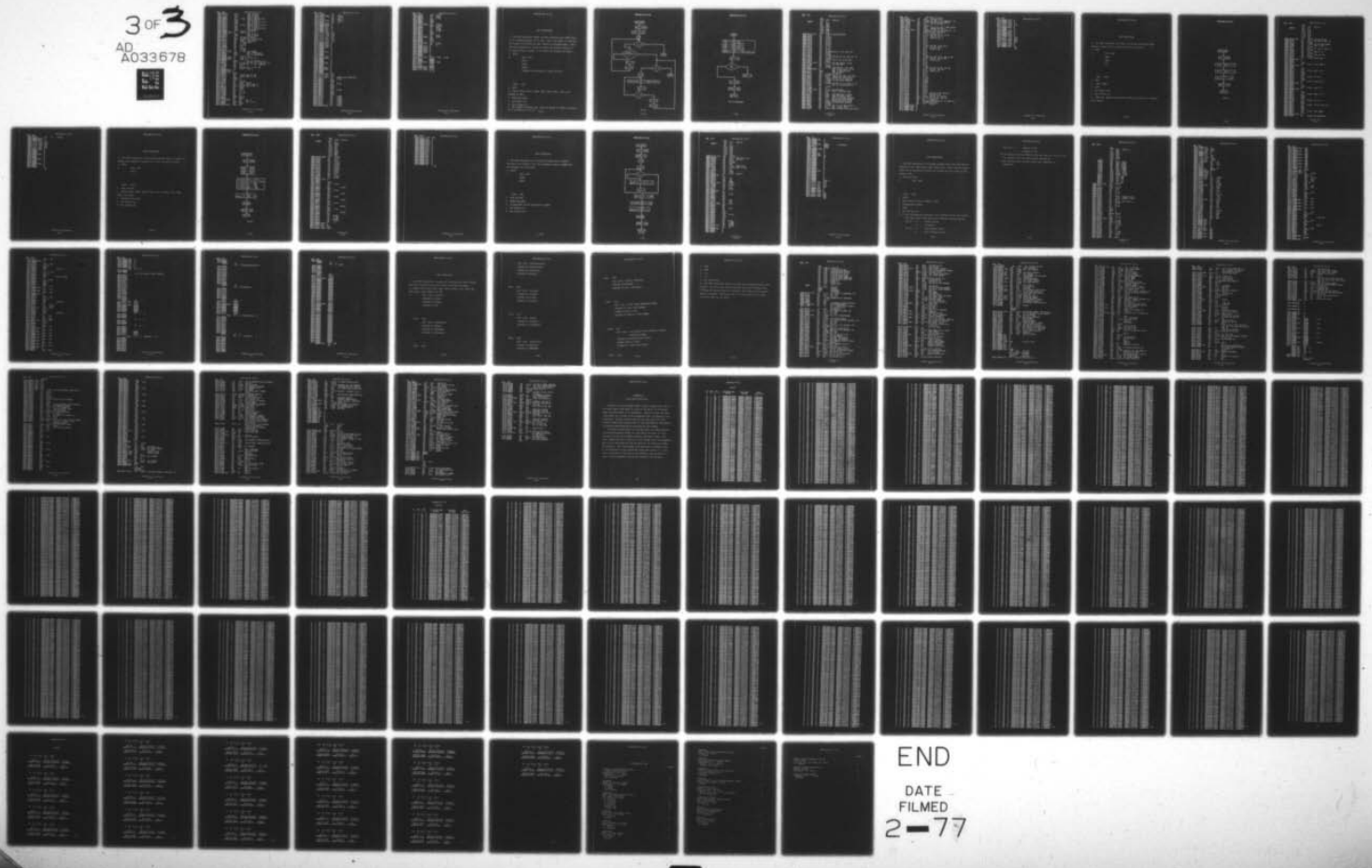


FIG. C16 (CONTINUED)

```
                        .NREL
                        .TITL   CPGN    ;9/19/73
            000010      .RDX    8
                        .ENT    CPGN
                        .ENT    GAIN1
                        .ENT    ANAR1
                        .ENT    BTAN1
                        .EXTN   TRG1
                        .EXTN   FDV1
                        .EXTN   LYVEL
                        .EXTN   FFSQ
                        .EXTN   FFSB
                        .EXTN   FFSR
                        .EXTN   FFML
                        .EXTN   FFDV
                        .EXTN   FFAD
                        .EXTN   FFLD
00000'054552 CPGN:      STA     3,RETRN ;SAVE RETURN ADR.
00001'031400            LDA     2,0,3
00002'020552            LDA     0,INC1
00003'143000            ADD     2,0
00004'040420            STA     0,ZAD1
00005'040441            STA     0,ZAD2
00006'040500            STA     0,ZAD3
00007'040507            STA     0,ZAD5
00010'020545            LDA     0,INC2
00011'143000            ADD     2,0
00012'040416            STA     0,TGAD1
00013'040452            STA     0,TGAD2
00014'020542            LDA     0,INC3
00015'143000            ADD     2,0
00016'040467            STA     0,TGAD3
00017'020540            LDA     0,INC4
00020'143000            ADD     2,0
00021'040413            STA     0,SNAD1
00022'050531            STA     2,DATAD
00023'006535            JSR     @,FSQR  ;Z ^ 2
00024'000000 ZAD1:      0               ;ADR. OF Z
00025'000166'           TEMA1           ;ADR. OF RESULT
00026'006533            JSR     @,FSUB  ;Z^2 - VT ^ 2
00027'000166'           TEMA1           ;ADR. OF RESULT
00030'000000 TGAD1:     0       ;ADR. OF VT^2
00031'000171'           TEMB1           ;ADR. OF RESULT
00032'006527            JSR     @,FSUB  ;Z^2 - VS^2
00033'000166'           TEMA1           ;ADR. OF Z^2
00034'000000 SNAD1:     0       ;ADR. OF VS^2
00035'000174'           TEMC1           ;ADR. OF RESULT
00036'006524            JSR     @,FSQT  ;SQRT(Z^2-VT^2)
00037'000171'           TEMB1           ;ADR. OF Z^2-VT^2
00040'000171'           TEMB1           ;ADR. OF RESULT
00041'006521            JSR     @,FSQT  ;SQRT(Z^2-VS^2
00042'000174'           TEMC1           ;ADR. OF Z^2-VS^2
00043'000174'           TEMC1           ;ADR. OF RESULT
00044'006517            JSR     @,FMUL  ;HOR. RNG. * Z
00045'177777            TRG1            ;ADR. OF HOR. RANGE
00046'000000 ZAD2:      0               ;ADR. OF Z
00047'000166'           TEMA1           ;ADR. OF RESULT
00050'006513            JSR     @,FMUL  ;ABOVE * DERIVATIVE
```

AD-A033 678 NAVAL SURFACE WEAPONS CENTER WHITE OAK LAB SILVER SP--ETC F/G 9/2
REAL TIME THREE LAYER OCEAN MODEL.(U)
APR 76 P J CRAUN
UNCLASSIFIED NSWC/WOL/TR-75-115 NL

3 OF 3
AD A033678



END
DATE FILMED
2-77

```
00051'000166'          TEMA1           ;ADR. OF RESULT
00052'177777           FDV1            ;ADR. OF DERIV.
00053'000166'          TEMA1           ;ADR. OF RESULT
00054'006507           JSR     @.FMUL  ;ABOVE * SQRT(Z^2-VT^2)
00055'000166'          TEMA1           ;ADR. OF RESULT
00056'000171'          TEMB1           ;ADR. OF SQRT (Z^2-VT^2)
00057'000166'          TEMA1           ;ADR. OF RESULT
00060'006503           JSR     @.FMUL  ;ABOVE * SQRT (Z^2-VS^2)
00061'000166'          TEMA1           ;ADR. OF RESULT
00062'000174'          TEMC1           ;ADR. OF SQRT (Z^2-VS^2)
00063'000166'          TEMA1           ;ADR. OF RESULT
00064'006500           JSR     @.FDIV  ;VT^2/ABOVE
00065'000000 TGAD2:    0       ;ADR. OF VT^2
00066'000166'          TEMA1           ;ADR. OF RESULT
00067'000166'          TEMA1           ;ADR. OF RESULT
00070'020477           LDA     0.TEMA2 ;GET RESULT
00071'101113           MOVL#   0.0.SNC ;SKIP IF RESULT NEG.
00072'000407           JMP     ARND1   ;JUMP AROUND
00073'024475           LDA     1.TEMA3 ;NEGATE
00074'124405           NEG     1.1.SNR
00075'100401           NEG     0.0.SKP
00076'100000           COM     0.0
00077'040470           STA     0.TEMA2
00100'044470           STA     1.TEMA3
00101'006461 ARND1:    JSR     @ .FSQT ;SQRT (ABOVE)
00102'000166'          TEMA1           ;ADR. OF POWER GAIN
00103'000200'          GAIN1           ;ADR. OF VOLTAGE GAIN
00104'006460           JSR     @.FDIV  ;VT/Z
00105'000000 TGAD3:    0       ;ADR. OF TG. SND. VEL.
00106'000000 ZAD3:     0       ;ADR. OF Z
00107'000203'          ANAR1           ;ADR. OF SINE ANG. AT TG.
00110'030455           LDA     2..LYVL ;GET ADR. OF LY. SND. VEL. TB.
00111'020466           LDA     0.INCRM ;BOT. LY. VEL. INCREMENT
00112'113000           ADD     0.2
00113'050402           STA     2.BTVLA ;BOT. LY. VEL. ADR.
00114'006450           JSR     @.FDIV  ;V BOT./Z
00115'000000 BTVLA:    0
00116'000000 ZAD5:     0
00117'000207'          BTAN1
00120'034433           LDA     3.DATAD ;DATA TB. ADR.
00121'025427           LDA     1.27.3  ;BOT. LY. NO.
00122'125220           MOVZR   1.1
00123'125220           MOVZR   1.1
00124'125005           MOV     1.1.SNR
00125'000423           JMP     FNGNC   ;END UP
00126'021432           LDA     0.32.3  ;NO. OF HALF CYC.
00127'101112           MOVL#   0.0.SZC ;SKIP IF NOT -1
00130'000420           JMP     FNGNC
00131'025430           LDA     1.30.3
00132'152400           SUB     2.2
00133'125005           MOV     1.1.SNR
00134'151400           INC     2.2
00135'145000           MOV     2.1
00136'101213           MOVR#   0.0.SNC
00137'000404           JMP     EVNO
00140'101400 ODNO:     INC     0.0     ;NO. +1
00141'101220           MOVZR   0.0     ;(NO. +1)/2
00142'000403           JMP     ARND2
00143'101220 EVNO:     MOVZR   0.0
```

LISTING C16 (Continued)

```
00144'123000          ADD     1.0
00145'040441 ARND2:   STA     0.NOBTL
00146'101004          MOV     0.0.SZR
00147'004445          JSR     ADBTL
00150'034402 FNGNC:   LDA     3.RETRN
00151'001401          JMP     1.3
00152'000000 RETRN:   0
00153'000000 DATAD:   0
00154'000023 INC1:    23
00155'000015 INC2:    15
00156'000007 INC3:    7
00157'000012 INC4:    12
00160'177777 .FSQR:   FFSQ
00161'177777 .FSUB:   FFSB
00162'177777 .FSQT:   FFSR
00163'177777 .FMUL:   FFML
00164'177777 .FDIV:   FFDV
00165'177777 .LYVL:   LYVEL
00166'000000 TEMA1:   0
00167'000000 TEMA2:   0
00170'000000 TEMA3:   0
00171'000000 TEMB1:   0
00172'000000          0
00173'000000          0
00174'000000 TEMC1:   0
00175'000000          0
00176'000000          0
00177'000011 INCRM:   11
00200'000000 GAIN1:   0
00201'000000          0
00202'000000          0
00203'000000 ANAR1:   0
00204'000000          0
00205'000000          0
00206'000000 NOBTL:   0
00207'000000 BTAN1:   0
00210'000000          0
00211'000000          0
00212'177777 .FADD:   FFAD
00213'177777 .FFLD:   FFLD
00214'054447 ADBTL:   STA     3.RETUN ;SAVE RETURN ADR.
00215'006743          JSR     @.FSQR
00216'000207'         BTAN1
00217'000267'         TEMD1
00220'006743          JSR     @.FMUL
00221'000267'         TEMD1
00222'000275'         BCNS1
00223'000267'         TEMD1
00224'006766          JSR     @.FADD
00225'000267'         TEMD1
00226'000272'         ACNS1
00227'000267'         TEMD1
00230'024450          LDA     1.ZERO1
00231'044433          STA     1.TEME1
00232'024447          LDA     1.ZERO2
00233'044432          STA     1.TEME2
00234'024446          LDA     1.ZERO3
00235'044431          STA     1.TEME3
00236'020750 BLOOP:   LDA     0.NOBTL
```

LISTING C16 (Continued)

```
 00237'101223          MOVZR   0.0.SNC
 00240'000405          JMP     ARND5
 00241'006722          JSR     @.FMUL
 00242'000267'         TEMD1
 00243'000264'         TEME1
 00244'000264'         TEME1
 00245'020741 ARND5:   LDA     0.NOBTL
 00246'101225          MOVZR   0.0.SNR
 00247'000406          JMP     ARND4
 00250'040736          STA     0.NOBTL
 00251'006707          JSR     @.FSQR
 00252'000267'         TEMD1
 00253'000267'         TEMD1
 00254'000762          JMP     BLOOP
 00255'006706 ARND4:   JSR     @.FMUL
 00256'000264'         TEME1
 00257'000200'         GAIN1
 00260'000200'         GAIN1
 00261'034402 ENDBL:   LDA     3.RETUN
 00262'001400          JMP     0.3
 00263'000000 RETUN:   0
 00264'000000 TEME1:   0
 00265'000000 TEME2:   0
 00266'000000 TEME3:   0
 00267'000000 TEMD1:   0
 00270'000000          0
 00271'000000          0
 00272'037777 ACNS1:   037777  ;.3162  (-10 DB)
 00273'050400          050400
 00274'000000          000000
 00275'040000 BCNS1:   040000  ;.6838
 00276'053577          053577
 00277'177777          177777
 00300'040000 ZERO1:   040000
 00301'077777 ZERO2:   077777
 00302'177777 ZERO3:   177777
                       .E  ND
```

LISTING C16 (Continued)

SORT SUBROUTINE

1. The SORT subroutine places ray path solutions into TSIBS based on the propagation gain of the ray. Only a set number of solutions are stored in the table and are ordered by decreasing gain. Each time the subroutine is called it places the present solution in its proper place, by gain, in the table and reorders the table.

2. NR1A2

3.
```
        JSR@ .SORT
        BGDAT
        TSNIB
        TSIBS
        (ADDRESS OF RAY PATH'S z LIMITS IN A1ZL)
    .
    .
    .
.SORT:  SORT
```

4. FPMP

5. TSNIB, TSIBS, GAIN1, CODEW, TTM1, ANAR1, TRG1, ZVAL1, and ADDRESS OF ZMAX1

6. TSNIB and TSIBS

7. See Figure C17.

8. See Listing C17.

9. The number of largest gain solutions stored in TSIBS is variable but is presently set to 16.

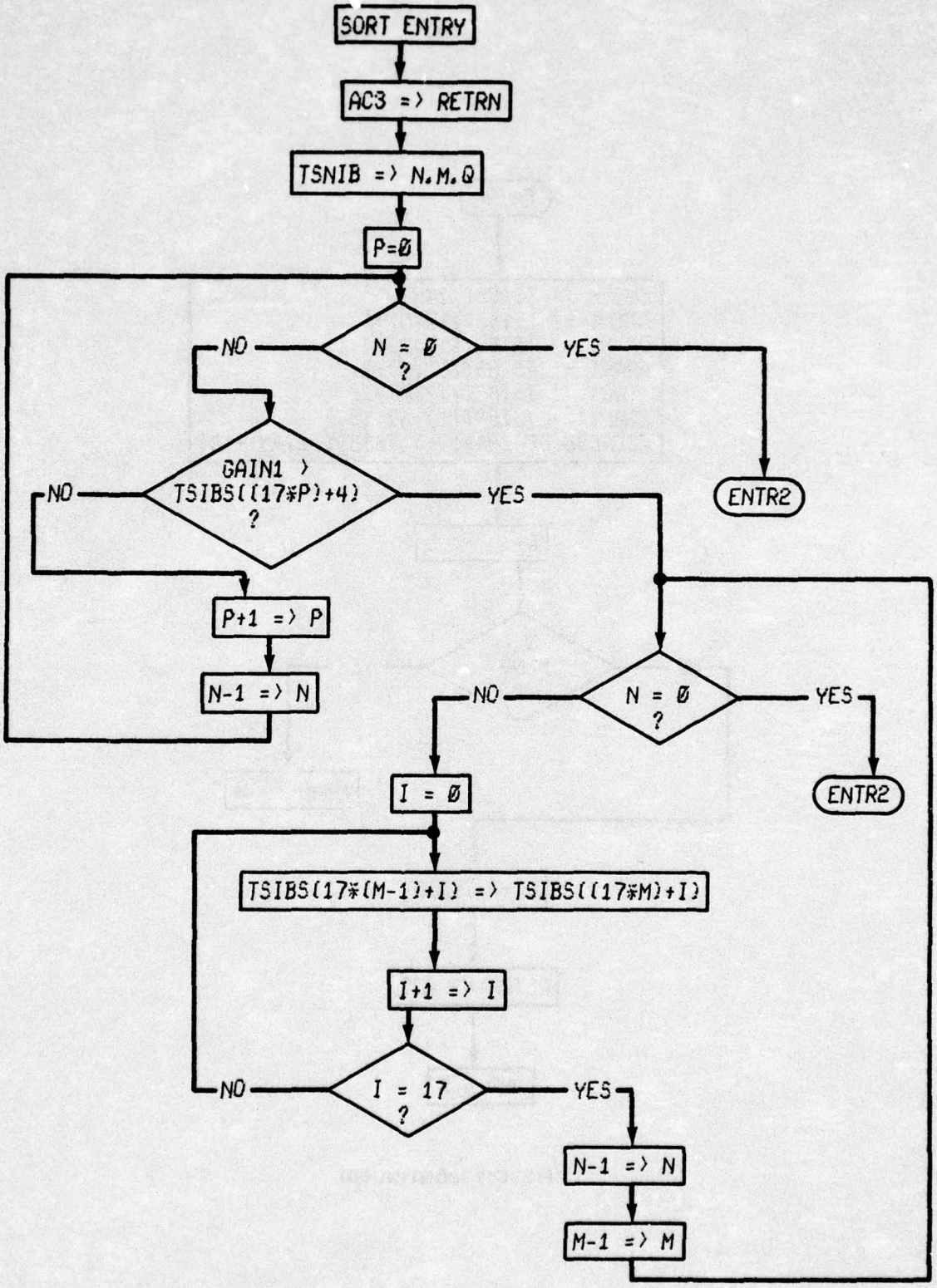

SORT ENTRY
AC3 => RETRN
TSNIB => N.M.Q
P=Ø
N = Ø ?
NO
YES
ENTR2
GAIN1 > TSIBS((17*P)+4) ?
NO
YES
P+1 => P
N-1 => N
N = Ø ?
NO
YES
ENTR2
I = Ø
TSIBS(17*(M-1)+I) => TSIBS((17*M)+I)
I+1 => I
I = 17 ?
NO
YES
N-1 => N
M-1 => M

FIG. C17

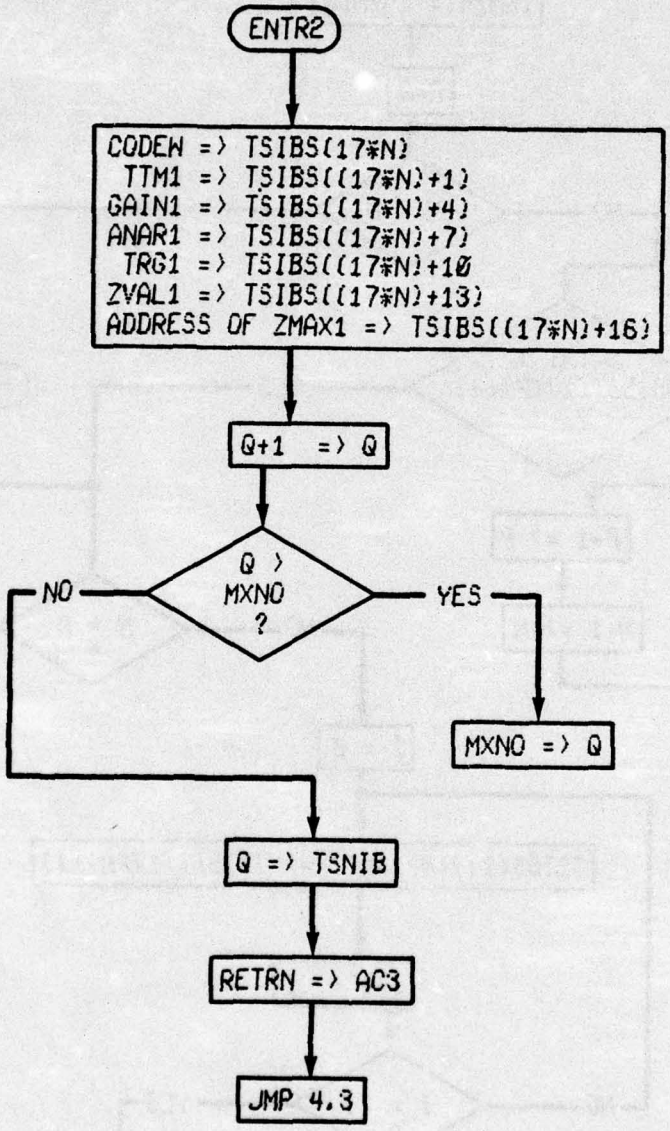


FIG. C17 (CONTINUED)

```
                    .NREL
                    .TITL   SORT    ;03/13/74
        000010      .RDX    8
                    .ENT    SORT
                    .ENT    MXNO
                    .EXTN   GAIN1
                    .EXTN   TTM1
                    .EXTN   ANAR1
                    .EXTN   TRG1
                    .EXTN   FFSB
00000'054547 SORT:  STA     3.RETRN ;SAVE RETURN ADR.
00001'031400        LDA     2.0.3
00002'050571        STA     2.DATAD
00003'021022        LDA     0.22.2
00004'040561        STA     0.CODEW
00005'021401        LDA     0.1.3
00006'040542        STA     0.NIBSA
00007'021402        LDA     0.2.3
00010'040543        STA     0..IBST
00011'021403        LDA     0.3.3
00012'040560        STA     0..ZMXA
00013'022535        LDA     @0.NIBSA;GET NO. OF INT. BASIC SOL.
00014'040535        STA     0.NIBS
00015'040535        STA     0.CNTR1
00016'030535        LDA     2..IBST ;GET ADR. OF INT. BASIC SOL. TB.
00017'050535        STA     2.PNTR1
00020'101005        MOV     0.0.SNR ;SKIP IF NO. IS NON ZERO
00021'000446        JMP     ENTR2
00022'020533 LOOP2: LDA     0.INCR1 ;GET ADR. INCREM. TO GAIN
00023'113000        ADD     0.2     ;SET GAIN ADR.
00024'050402        STA     2.ADRGN
00025'006531        JSR     @.FSUB  ;GAIN FROM TB. - SOL. GAIN
00026'000000 ADRGN: 0               ;ADR. OF GAIN FROM I.B.S.TB.
00027'177777        GAIN1           ;ADR. OF SOLUTION GAIN
00030'000157'       TEMA1           ;ADR. OF RESULT
00031'020527        LDA     0.TEMA2 ;GET RESULT
00032'101103        MOVL    0.0.SNC ;SKIP IF SOL. GAIN > TB. GAIN
00033'000426        JMP     ENTR1   ;COMPARE NEXT GAIN FROM TB.
00034'030516        LDA     2.CNTR1 ;GET NO. OF INT. BASIC SOL.
00035'024525        LDA     1.INCR2 ;GET DATA BLOCK INCREMENT
00036'044525        STA     1.CNTR2
00037'020515        LDA     0.PNTR1 ;GET ADR. OF INT. BASIC SOL. TB.
00040'073301        MUL             ;ADR. OF LAST DATA BLOCK + 1
00041'044523        STA     1.PNTR2
00042'131000        MOV     1.2
00043'021357 LOOP1: LDA     0.-21.2 ;GET DATA BLOCK
00044'041000        STA     0.0.2   ;MOVE IT ONE BLOCK DOWN
00045'151400        INC     2.2
00046'014515        DSZ     CNTR2   ;SKIP WHEN BLOCK IS MOVED
00047'000774        JMP     LOOP1   ;MOVE NEXT WORD IN BLOCK
00050'014502        DSZ     CNTR1   ;SKIP IF THIS WAS LAST BLOCK
00051'000402        JMP     .+2     ;SET UP NEXT BLOCK TRANFER
00052'000415        JMP     ENTR2   ;STORE NEW SOLUTION IN TB.
00053'020507        LDA     0.INCR2 ;GET DATA BLOCK INCREMENT
00054'040507        STA     0.CNTR2
00055'030507        LDA     2.PNTR2 ;GET I.B.S.TB. ADR. POINTER
00056'112400        SUB     0.2     ;ADR. - BLOCK LENGTH
00057'050505        STA     2.PNTR2 ;ADR. OF WHERE TO MOVE NEXT BLOCK
```

```
0002  SORT                          NSWC/WOL/TR 75-115
  00060'000763          JMP     LOOP1   ;MOVE NEXT BLOCK
  00061'030473 ENTR1:   LDA     2.PNTR1 ;GET ADR. OF INT. BASIC SOL. TB.
  00062'020500          LDA     0.INCR2 ;GET DATA BLOCK INCREMENT
  00063'113000          ADD     0.2     ;SET UP NEXT ADR.
  00064'050470          STA     2.PNTR1
  00065'014465          DSZ     CNTR1   ;SKIP IF ALL SOL.'S WERE CHECKED
  00066'000734          JMP     LOOP2   ;COMPARE NEXT GAIN
  00067'030465 ENTR2:   LDA     2.PNTR1 ;GET ADR. OF INT. BASIC SOL. TB.
  00070'020475          LDA     0.CODEW:GET SOL. CODE WORD
  00071'041000          STA     0.0.2   ;STORE IN TB.
  00072'034474          LDA     3..TTM1 ;GET ADR. OF SOL. TM. DY.
  00073'021400          LDA     0.0.3   ;GET SOL. TM. DY.
  00074'041001          STA     0.1.2   ;STORE IN TB.
  00075'021401          LDA     0.1.3
  00076'041002          STA     0.2.2
  00077'021402          LDA     0.2.3
  00100'041003          STA     0.3.2
  00101'034466          LDA     3..GAIN ;GET ADR. OF SOL GAIN
  00102'021400          LDA     0.0.3   ;GET SOL. GAIN
  00103'041004          STA     0.4.2   ;STORE IN TB.
  00104'021401          LDA     0.1.3
  00105'041005          STA     0.5.2
  00106'021402          LDA     0.2.3
  00107'041006          STA     0.6.2
  00110'034460          LDA     3..ANAR ;GET ADR. OF SOL. ANG. OF ARR.
  00111'021400          LDA     0.0.3   ;GET SOL. ANG. OF ARR
  00112'041007          STA     0.7.2   ;STORE IN TB.
  00113'021401          LDA     0.1.3
  00114'041010          STA     0.10.2
  00115'021402          LDA     0.2.3
  00116'041011          STA     0.11.2
  00117'034452          LDA     3..TRG1 ;GET ADR. OF SOL. HOR. RNG.
  00120'021400          LDA     0.0.3   ;GET SOL. HOR. RNG.
  00121'041012          STA     0.12.2  ;STORE IN TB.
  00122'021401          LDA     0.1.3
  00123'041013          STA     0.13.2
  00124'021402          LDA     0.2.3
  00125'041014          STA     0.14.2
  00126'020444          LDA     0..ZMXA
  00127'041020          STA     0.20.2
  00130'034443          LDA     3.DATAD
  00131'021423          LDA     0.23.3
  00132'041015          STA     0.15.2
  00133'021424          LDA     0.24.3
  00134'041016          STA     0.16.2
  00135'021425          LDA     0.25.3
  00136'041017          STA     0.17.2
  00137'020412          LDA     0.NIBS  ;GET NO. OF INT. BASIC SOL.
  00140'101400          INC     0.0     ;ADD ONE TO NO.
  00141'024433          LDA     1.MXNO  ;GET MAX. NO. ALLOWED
  00142'106513          SUBL#   0.1.SNC ;SKIP IF NO. > MAX. NO.
  00143'105000          MOV     0.1     ;USE NEW NO.
  00144'046404          STA     @1.NIBSA:STORE NEW NO. OF INT. BASIC SOL.
  00145'034402          LDA     3.RETRN ;GET RETURN
  00146'001404          JMP     4.3     ;RETURN
  00147'000000 RETRN:   0
  00150'000000 NIBSA:   0
  00151'000000 NIBS:    0
  00152'000000 CNTR1:   0
```

LISTING C17 (Continued)

```
0003  SORT
 00153'000000 .IBST:  0
 00154'000000 PNTR1:  0
 00155'000004 INCR1:  4
 00156'177777 .FSUB:  FFSB
 00157'000000 TEMA1:  0
 00160'000000 TEMA2:  0
 00161'000000         0
 00162'000021 INCR2:  21
 00163'000000 CNTR2:  0
 00164'000000 PNTR2:  0
 00165'000000 CODEW:  0
 00166'177777 .TTM1:  TTM1
 00167'000027'.GAIN:  GAIN1
 00170'177777 .ANAR:  ANAR1
 00171'177777 .TRG1:  TRG1
 00172'000000 .ZMXA:  0
 00173'000000 DATAD:  0
 00174'000020 MXNO:   20
                      .END
```

LISTING C17 (Continued)

CPHR SUBROUTINE

1. The CPHR subroutine calculates the actual horizontal range between a target and sonobuoy given their positions.

2. MNMX

3.
```
        JSR@ .CPHR
        .SnXH
        .TmXH
        A1HR
    .
    .
    .
.CPHR:  CPHR
```

4. FPMP

5. .SnXH, .TmXH

6. A1HR

7. See Figure C18.

8. See Listing C18.

9. .SnXH and .TmXH are fixed point numbers and A1HR is a floating point number.

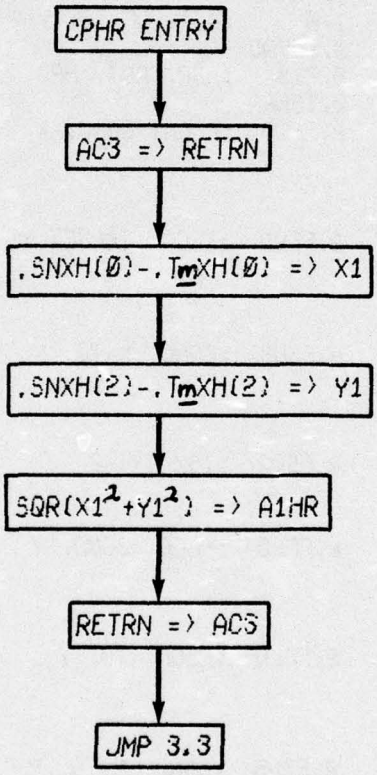

CPHR ENTRY
AC3 => RETRN
.SNXH(Ø)-.TmXH(Ø) => X1
.SNXH(2)-.TmXH(2) => Y1
SQR(X1²+Y1²) => A1HR
RETRN => AC3
JMP 3,3

FIG. C18

```
0001  CPHR
                          .NREL
                          .TITL   CPHR    ;03/4/74
          000010          .RDX    8
                          .ENT    CPHR
                          .EXTN   FFSB
                          .EXTN   FFSQ
                          .EXTN   FFAD
                          .EXTN   FFSR
                          .EXTN   FFLD
00000'054463 CPHR:        STA     3.RETRN ;SAVE RETURN ADR.
00001'021400              LDA     0.0.3   ;GET ADR. OF SONO. TB.
00002'040413              STA     0.SNXAD
00003'024461              LDA     1.DBINC ;GET DATA BASE INCREM.
00004'123000              ADD     1.0     ;ADR. OF SONO. Y
00005'040427              STA     0.SNYAD
00006'021401              LDA     0.1.3   ;GET ADR. OF TARGET TB.
00007'040412              STA     0.TGXAD
00010'123000              ADD     1.0     ;ADR. OF TG. Y
00011'040427              STA     0.TGYAD
00012'021402              LDA     0.2.3   ;ADR. ACT. HRG.
00013'040445              STA     0.TSHRA
00014'006451              JSR     @.FFLD  ;FLOAT SONO. X
00015'000000 SNXAD:       0
00016'000004              4
00017'000072'             TEMA1
00020'006445              JSR     @.FFLD  ;FLOAT TARGET X
00021'000000 TGXAD:       0
00022'000004              4
00023'000075'             TEMB1
00024'006442              JSR     @.FSUB  ;SONO. X-TG. X
00025'000072'             TEMA1
00026'000075'             TEMB1
00027'000100'             TEMC1
00030'006437              JSR     @.FSQR  ;(SX-TX)^2
00031'000100'             TEMC1
00032'000103'             TEMD1
00033'006432              JSR     @.FFLD  ;FLOAT SONO. Y
00034'000000 SNYAD:       0
00035'000004              4
00036'000072'             TEMA1
00037'006426              JSR     @.FFLD  ;FLOAT TG. Y
00040'000000 TGYAD:       0
00041'000004              4
00042'000075'             TEMB1
00043'006423              JSR     @.FSUB  ;SONO. Y-TG. Y
00044'000072'             TEMA1
00045'000075'             TEMB1
00046'000100'             TEMC1
00047'006420              JSR     @.FSQR  ;(SY-TY)^2
00050'000100'             TEMC1
00051'000072'             TEMA1
00052'006416              JSR     @.FADD  ;(SX-TX)^2+(SY-TY)^2
00053'000072'             TEMA1
00054'000103'             TEMD1
00055'000075'             TEMB1
00056'006413              JSR     @.FSQT  ;SQRT (ABOVE)
00057'000075'             TEMB1
00060'000000 TSHRA:       0
00061'034402              LDA     3.RETRN ;GET RETURN ADR.
```

LISTING C18

```
0002  CPHR
 00062'001403            JMP     3,3     ;RETURN
 00063'000000 RETRN:     0
 00064'000002 DBINC:     2
 00065'177777 .FFLD:     FFLD
 00066'177777 .FSUB:     FFSB
 00067'177777 .FSQR:     FFSQ
 00070'177777 .FADD:     FFAD
 00071'177777 .FSQT:     FFSR
 00072'000000 TEMA1:     0
 00073'000000            0
 00074'000000            0
 00075'000000 TEMB1:     0
 00076'000000            0
 00077'000000            0
 00100'000000 TEMC1:     0
 00101'000000            0
 00102'000000            0
 00103'000000 TEMD1:     0
 00104'000000            0
 00105'000000            0
                         .END
```

LISTING C18 (Continued)

DSPRP SUBROUTINE

1. The DSPRP subroutine is an optional program which is called to display the parameters computed for a valid ray path solution.

2. NR1A2

3.
```
          JSR@ .DSPP
          BGDAT
     .
     .
     .
    .DSPP:   DSPRP
```

4. FPMP and DUMP

5. TPNUM, BTNUM, DIRMD, NUMCY, ZVAL1, TDV1 or FDV1, TRG1, TTM1, GAIN1, and ANAR1.

6. Displays above data.

7. See Figure C19.

8. See Listing C19.

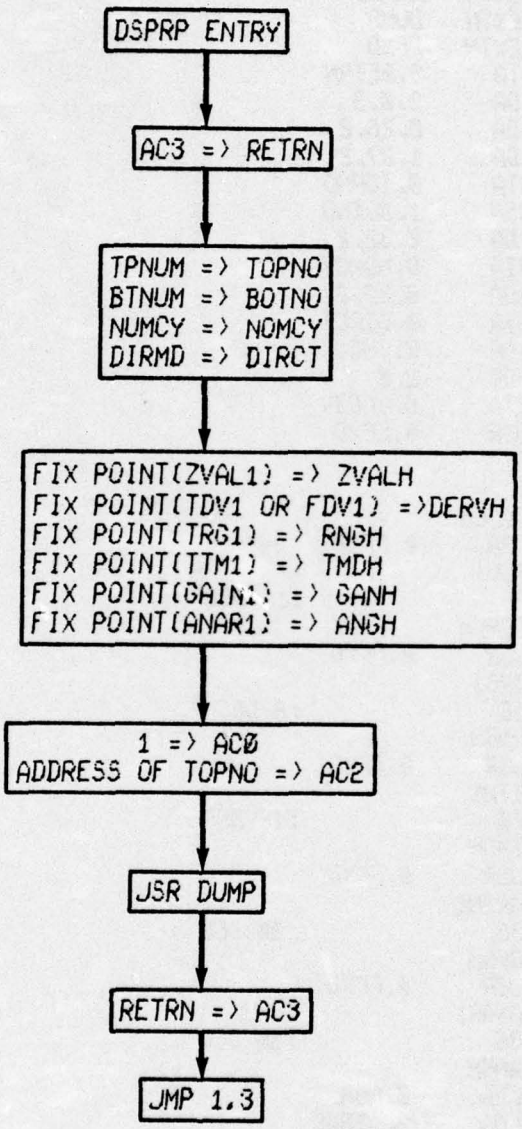

DSPRP ENTRY
AC3 => RETRN
TPNUM => TOPNO
BTNUM => BOTNO
NUMCY => NOMCY
DIRMD => DIRCT
FIX POINT(ZVAL1) => ZVALH
FIX POINT(TDV1 OR FDV1) =>DERVH
FIX POINT(TRG1) => RNGH
FIX POINT(TTM1) => TMDH
FIX POINT(GAIN1) => GANH
FIX POINT(ANAR1) => ANGH
1 => AC0
ADDRESS OF TOPNO => AC2
JSR DUMP
RETRN => AC3
JMP 1,3

FIG. C19

```
                        .NREL
                        .TITL   DSPRP   ;3/13/74
            000010      .RDX    8
                        .ENT    DSPRP
                        .ENT    TOPNO
                        .EXTN   TDV1
                        .EXTN   TRG1
                        .EXTN   TTM1
                        .EXTN   GAIN1
                        .EXTN   ANAR1
                        .EXTN   DUMP
                        .EXTN   FFXD
00000'054452 DSPRP:     STA     3.RETRN
00001'031400            LDA     2.0.3
00002'021026            LDA     0.26.2
00003'025027            LDA     1.27.2
00004'040454            STA     0.TOPNO
00005'044454            STA     1.BOTNO
00006'021032            LDA     0.32.2
00007'040453            STA     0.NOMCY
00010'021030            LDA     0.30.2
00011'040452            STA     0.DIRCT
00012'020441            LDA     0.INC1
00013'143000            ADD     2.0
00014'040402            STA     0..ADZV
00015'006437            JSR     @.FFXD
00016'000000 .ADZV:     0
00017'000007            7
00020'000064'           ZVALH
00021'006433            JSR     @.FFXD
00022'177777            TDV1
00023'000020            20              ;16 DEC
00024'000066'           DERVH
00025'006427            JSR     @.FFXD
00026'177777            TRG1
00027'000010            10              ;8 DEC
00030'000070'           RNGH
00031'006423            JSR     @.FFXD
00032'177777            TTM1
00033'000020            20              ;16 DEC
00034'000072'           TMDH
00035'006417            JSR     @.FFXD
00036'177777            GAIN1
00037'000036            36              ;30 DEC
00040'000074'           GANH
00041'006413            JSR     @.FFXD
00042'177777            ANAR1
00043'000036            36              ;30 DEC
00044'000076'           ANGH
00045'020412            LDA     0.NOM
00046'030407            LDA     2..TBAD
00047'006407            JSR     @.DUMP
00050'034402            LDA     3.RETRN
00051'001401            JMP     1.3
00052'000000 RETRN:     0
00053'000023 INC1:      23
00054'177777 .FFXD:     FFXD
00055'000060'.TBAD:     TOPNO
```

LISTING C19

```
00056'177777 .DUMP:   DUMP
00057'000001 NOM:     1
00060'000000 TOPNO:   0
00061'000000 BOTNO:   0
00062'000000 NOMCY:   0
00063'000000 DIRCT:   0
00064'000000 ZVALH:   0
00065'000000 ZVALL:   0
00066'000000 DERVH:   0
00067'000000 DERVL:   0
00070'000000 RNGH:    0
00071'000000 RNGL:    0
00072'000000 TMDH:    0
00073'000000 TMDL:    0
00074'000000 GANH:    0
00075'000000 GANL:    0
00076'000000 ANGH:    0
00077'000000 ANGL:    0
                      .END
```

LISTING C19 (Continued)

TOTG SUBROUTINE

1. The TOTG subroutine is an optional program which computes the sum of the squares of all the propagation gains in m1BST and then displays it in decibels.
2. PROPM
3.
```
        JSR@ .TOTG
        m1NBS
        m1BST
    .
    .
    .
.TOTG:  TOTG
```
4. FPMP and DUMP
5. m1NBS and m1BST
6. Average gain for all ray paths in m1BST
7. See Figure C20.
8. See Listing C20.

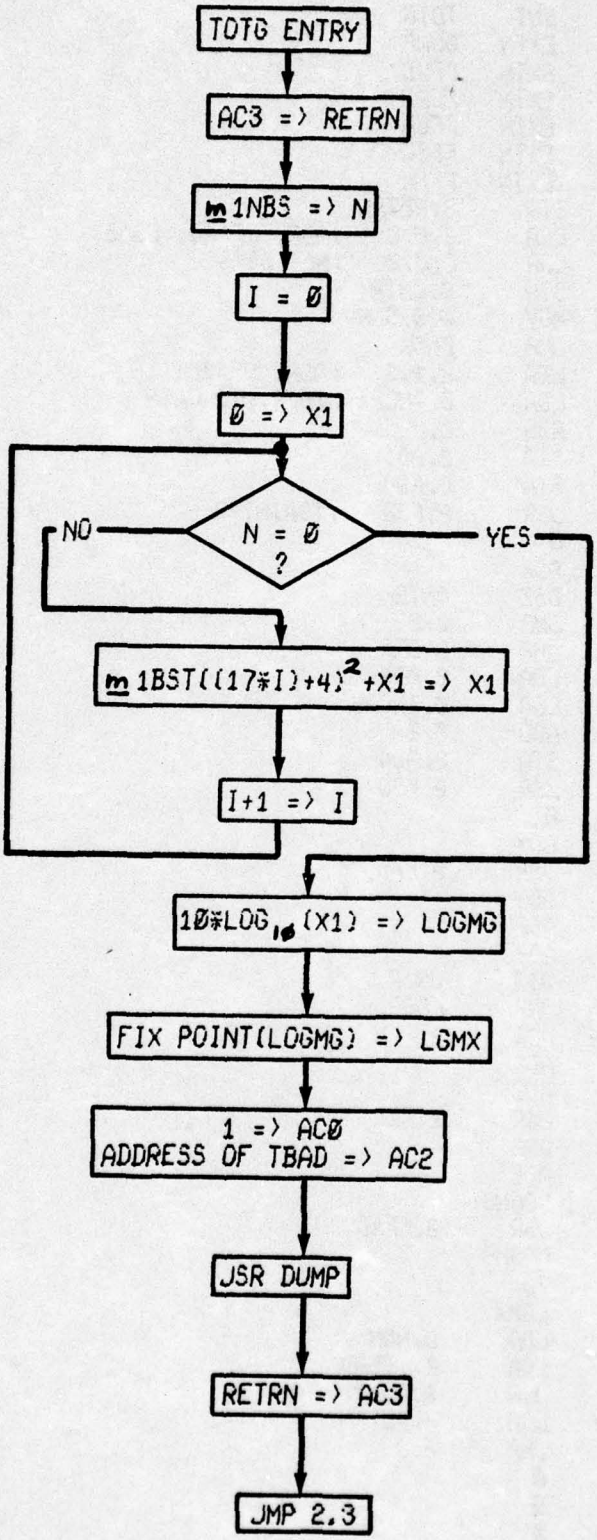

TOTG ENTRY
AC3 => RETRN
m 1NBS => N
I = Ø
Ø => X1
N = Ø ?
NO
YES
m 1BST((17*I)+4)^2+X1 => X1
I+1 => I
10*LOG10(X1) => LOGMG
FIX POINT(LOGMG) => LGMX
1 => AC0
ADDRESS OF TBAD => AC2
JSR DUMP
RETRN => AC3
JMP 2,3

FIG. C20

```
                        .NREL
                        .TITL   TOTG    ;09/6/74
        000010          .RDX    8
                        .ENT    TOTG
                        .EXTN   DUMP
                        .EXTN   FFXD
                        .EXTN   FFAD
                        .EXTN   FFLN
                        .EXTN   FFSQ
                        .EXTN   FFML
00000'054513 TOTG:      STA     3,RETRN
00001'031400            LDA     2,0,3   ;ADR. OF NO. BS'S
00002'021000            LDA     0,0,2   ;NO. BS'S
00003'040515            STA     0,CNTR
00004'101005            MOV     0,0,SNR
00005'000447            JMP     ENDX
00006'031401            LDA     2,1,3   ;ADR. OF BST
00007'020512            LDA     0,INCR1 ;INCR. TO GAIN
00010'113000            ADD     0,2
00011'050403            STA     2,AD1
00012'050414            STA     2,AD4
00013'006501            JSR     @.FSQ   ;(GAIN)^2
00014'000000 AD1:       0
00015'000056'           AD2
00016'014502            DSZ     CNTR
00017'000402            JMP     .+2
00020'000416            JMP     ENDRR
00021'030405 LOOP:      LDA     2,AD4
00022'020500            LDA     0,INCR2
00023'113000            ADD     0,2
00024'050402            STA     2,AD4
00025'006467            JSR     @.FSQ
00026'000000 AD4:       0
00027'000061'           AD3
00030'006467            JSR     @.FAD
00031'000061'           AD3
00032'000056'           AD2
00033'000056'           AD2
00034'014464            DSZ     CNTR
00035'000764            JMP     LOOP
00036'006457 ENDRR:     JSR     @.FLN
00037'000056'           AD2
00040'000056'           AD2
00041'006455            JSR     @.FML
00042'000056'           AD2
00043'000064'           AD6
00044'000067'           LOGMG
00045'006456            JSR     @.FFXD
00046'000067'           LOGMG
00047'000020            20
00050'000105'           LGMX
00051'020421            LDA     0,NOM
00052'030453            LDA     2,.TBAD
00053'006451            JSR     @.DUMP
00054'034437 ENDX:      LDA     3,RETRN
00055'001402            JMP     2,3
00056'000000 AD2:       0
00057'000000            0
00060'000000            0
```

```
00061'000000 AD3:    0
00062'000000         0
00063'000000         0
00064'040003 AD6:    040003          ;4.342944819
00065'042574         042574
00066'137454         137454
00067'000000 LOGMG:  0
00070'000000         0
00071'000000         0
00072'000001 NOM:    1
00073'000050 TBAD:   50
00074'000050         50
00075'000000         0
00076'000000         0
00077'000000         0
00100'000000         0
00101'000000         0
00102'000000         0
00103'000000         0
00104'000000         0
00105'000000 LGMX:   0
00106'000000         0
00107'000000         0
00110'000000         0
00111'000000         0
00112'000000         0
00113'000000         RETRN:  0
00114'177777 .FSQ:   FFSQ
00115'177777 .FLN:   FFLN
00116'177777 .FML:   FFML
00117'177777 .FAD:   FFAD
00120'000000 CNTR:   0
00121'000004 INCR1:  4
00122'000021 INCR2:  21
00123'177777 .FFXD:  FFXD
00124'177777 .DUMP:  DUMP
00125'000073'.TBAD:  TBAD
                     .END
```

LISTING C20 (Continued)

DUMP SUBROUTINE

1. The DUMP subroutine is a display program which shows the results computed by the three layer ocean subroutines. There are two formats which can be displayed on either the cathode ray tube (CRT) or line printer (LPT).
2. DSPRP and TOTG
3.
```
        JSR@ .DUMP
        .
        .
        .
.DUMP:  DUMP
```
4. WRITE
5. Data tables formed in DSPRP or TOTG.
6. Displays data table.
7. NONE.
8. See Listing C21.
9. a) The following bit patterns in the switches of the CPU running the three layer ocean model give different display options.

```
BIT (0)  = 0   ;   Create display
         = 1   ;   No display
BIT (1)  = 0   ;   Long display format
         = 1   ;   Short display format
```

BIT (15) = 0 ; Display on CRT

1 ; Display on LPT

b) The display routines DSPRP and TOTG are used only off-line and not during a real time ASGS problem generation.

c) The long and short display formats are explained in Appendix D.

```
0001  DUMP

                        .NREL
                        .TITL   DUMP    ;05/16/74
                        .ENT    DUMP
                        .EXTN   SAVEL
                        .EXTN   SAVEC
                        .EXTN   SWIT
                        .EXTN   WRITE
                        .EXTN   INTER
        000010          .RDX    8
        140000          .DMR    DS00 = 140000
        163400          .DMR    DD07 = 163400
        164400          .DMR    DD09 = 164400
        164000          .DMR    DD08 = 164000
        170000          .DMR    DD16 = 170000
        177000          .DMR    DD30 = 177000
        163646          .DUSR   D7106 = 163646
        164646          .DUSR   D9106 = 164646
        170251          .DUSR   D16109 = 170251
        000040          .DUSR   I2F0 = 040
        000020          .DUSR   I1F0 = 020
        000246          .DUSR   ITF6 = 246
        000171          .DUSR   I7F9 = 171
        000031          .DUSR   I1F9 = 031
00000'054443 DUMP:      STA     3,RETN
00001'074477            READS   3
00002'175122            MOVZL   3,3,SZC
00003'002440            JMP@    RETN
00004'034007            LDA     3,7
00005'054442            STA     3,SAV7
00006'034442            LDA     3,.AX
00007'054007            STA     3,7
00010'040512            STA     0,NOFL  ;NUMBER OF SETS
00011'050512            STA     2,SAV2  ;ADDRESS TO DATA
00012'102000            ADC     0,0
00013'040511            STA     0,LNNB  ;SET LINE TO =1
00014'020436            LDA     0,INTX
00015'040001            STA     0,1
00016'020435            LDA     0,IMSK
00017'062077            MSKO    0
00020'060177            INTEN
00021'060477            READS   0
00022'126000            ADC     1,1
00023'101233            MOVZR#  0,0,SNC
00024'126400            SUB     1,1
00025'046424            STA@    1,.SWIT
00026'060477 EXEC:      READS   0
00027'036415            LDA@    3,.SAVC
00030'101222            MOVZR   0,0,SZC
00031'036414            LDA@    3,.SAVL
00032'175004            MOV     3,3,SZR
00033'001777            JMP     -1,3
00034'004432            JSR     DSPX
00035'126400            SUB     1,1
00036'046407            STA@    1,.SAVL
00037'046405            STA@    1,.SAVC
00040'034407            LDA     3,SAV7
00041'054007            STA     3,7
00042'002401            JMP@    RETN
```

```
0002  DUMP
 00043'000000 RETN:   0
 00044'177777 .SAVC:  SAVEC
 00045'177777 .SAVL:  SAVEL
 00046'000000 DCNT:   0
 00047'000000 SAV7:   0
 00050'000026'.AX:    EXEC
 00051'177777 .SWIT:  SWIT
 00052'177777 INTX:   INTER
 00053'177700 IMSK:   177700
 00054'111000 CB2D:   MOV     0,2
 00055'102400         SUB     0,0
 00056'024403         LDA     1,C6
 00057'073301         MUL
 00060'001400         JMP     0,3
 00061'000550 C6:     000550
 00062'000000 ARYPR:  0
 00063'000000 CLBFR:  0
 00064'000000 CLFLG:  0
 00065'000000 FURD:   0
 00066'054433 DSPX:   STA     3,DRTN
 00067'024436 LINL:   LDA     1,M4
 00070'010434         ISZ     LNNB
 00071'101000         MOV     0,0
 00072'034435         LDA     3,TADR
 00073'030430 LINM:   LDA     2,SAV2
 00074'053400         STA@    2,0,3
 00075'010426         ISZ     SAV2
 00076'175400         INC     3,3
 00077'053400         STA@    2,0,3
 00100'175400         INC     3,3
 00101'125404         INC     1,1,SZR
 00102'000771         JMP     LINM
 00103'024423         LDA     1,M6
 00104'030417 LINN:   LDA     2,SAV2
 00105'053400         STA@    2,0,3
 00106'010415         ISZ     SAV2
 00107'010414         ISZ     SAV2
 00110'175400         INC     3,3
 00111'053400         STA@    2,0,3
 00112'175400         INC     3,3
 00113'125404         INC     1,1,SZR
 00114'000770         JMP     LINN
 00115'004441         JSR     OUTPT
 00116'014404         DSZ     NOFL
 00117'000750         JMP     LINL
 00120'002401         JMP@    DRTN
 00121'000000 DRTN:   0
 00122'000000 NOFL:   0
 00123'000000 SAV2:   0
 00124'000000 LNNB:   0
 00125'177774 M4:     -4
 00126'177772 M6:     -6.
 00127'000130'TADR:   TA01
 00130'000177'TA01:   AD01
 00131'000305'        XD01
 00132'000201'TA02:   AD02
 00133'000307'        XD02
 00134'000203'TA03:   AD03
 00135'000311'        XD03
```

LISTING C21 (Continued)

```
0003  DUMP
 00136'000205'TA04:   AD04
 00137'000313'        XD04
 00140'000226'TA05:   AD05
 00141'000324'        XD05
 00142'000230'TA06:   AD06
 00143'000325'        XD06
 00144'000253'TA07:   AD07
 00145'000315'        XD07
 00146'000255'TA08:   AD08
 00147'000317'        XD08
 00150'000257'TA09:   AD09
 00151'000321'        XD09
 00152'000232'TA10:   AD10
 00153'000326'        XD10
 00154'177777 .WRIT:  WRITE
 00155'000000 ORTN:   0
 00156'054777 OUTPT:  STA     3,ORTN
 00157'074477         READS   3
 00160'175120         MOVZL   3,3
 00161'175122         MOVZL   3,3,SZC
 00162'000516         JMP     SHRT
 00163'006771         JSR@    .WRIT
 00164'000535'        BLOX-10
 00165'000200         200
 00166'000332'        FRM1    ;TOP
 00167'140040         DS00    I2F0
 00170'000124'        LNNB
 00171'000000         0
 00172'006762         JSR@    .WRIT
 00173'000527'        BLOX-16
 00174'000200         200
 00175'000355'        FRM2
 00176'140020         DS00    I1F0
 00177'000000 AD01:   0
 00200'140020         DS00    I1F0
 00201'000000 AD02:   0
 00202'140040         DS00    I2F0
 00203'000000 AD03:   0
 00204'140020         DS00    I1F0
 00205'000000 AD04:   0
 00206'000000         0
 00207'006745         JSR@    .WRIT
 00210'000527'        BLOX-16
 00211'000200         200
 00212'000353'        FRM0            ;LINE FEED
 00213'000000         0
 00214'006740         JSR@    .WRIT
 00215'000527'        BLOX-16
 00216'000200         200
 00217'000376'        FRM3            ;PREV Z
 00220'000000         0
 00221'006733         JSR@    .WRIT
 00222'000527'        BLOX-16
 00223'000200         200
 00224'000433'        FRM4
 00225'163646         D7106
 00226'000000 AD05:   0
 00227'170251         D16109
 00230'000000 AD06:   0
```

LISTING C21 (Continued)

```
0004  DUMP
 00231'177031          DD30    I1F9
 00232'000000 AD10:    0
 00233'000000          0
 00234'006720          JSR@    .WRIT
 00235'000527'         BLOX-16
 00236'000200          200
 00237'000353'         FRM0            ;LINE FEED
 00240'000000          0
 00241'006713          JSR@    .WRIT
 00242'000527'         BLOX-16
 00243'000200          200
 00244'000442'         FRM5            ;PREVIOUS RANGE
 00245'000000          0
 00246'006706          JSR@    .WRIT
 00247'000527'         BLOX-16
 00250'000200          200
 00251'000514'         FRM6
 00252'164246          DD08    ITF6
 00253'000000 AD07:    0
 00254'170171          DD16    I7F9
 00255'000000 AD08:    0
 00256'177031          DD30    I1F9
 00257'000000 AD09:    0
 00260'000000          0
 00261'006673          JSR@    .WRIT
 00262'000527'         BLOX-16
 00263'000200          200
 00264'000353'         FRM0            ;LINE FEED
 00265'000000          0
 00266'034441          LDA     3,EIFG
 00267'054442          STA     3,CONT
 00270'006664 LP:      JSR@    .WRIT
 00271'000527'         BLOX-16
 00272'000200          200
 00273'000353'         FRM0            ;LINE FEED
 00274'000000          0
 00275'014434          DSZ     CONT
 00276'000772          JMP     LP
 00277'002656          JMP@    ORTN
 00300'006654 SHRT:    JSR@    .WRIT
 00301'000535'         BLOX-10
 00302'000200          200
 00303'000474'         FRM7
 00304'140020          DS00    I1F0
 00305'000000 XD01:    0
 00306'140020          DS00    I1F0
 00307'000000 XD02:    0
 00310'140040          DS00    I2F0
 00311'000000 XD03:    0
 00312'140020          DS00    I1F0
 00313'000000 XD04:    0
 00314'164246          DD08    ITF6
 00315'000000 XD07:    0
 00316'170171          DD16    I7F9
 00317'000000 XD08:    0
 00320'177031          DD30    I1F9
 00321'000000 XD09:    0
 00322'000000          0
 00323'002632          JMP@    ORTN
```

LISTING C21 (Continued)

```
0005  DUMP
 00324'000000 XD05:   0
 00325'000000 XD06:   0
 00326'000000 XD10:   0
 00327'000002 EIFG:   2
 00330'000000 FLGX:   0
 00331'000000 CONT:   0
              FRM1:   .TXT $  $
 00332'020040
 00333'000000
                      .TXT $  TOP  BOTTOM  CYCLES  VECTOR $
 00334'020040
 00335'047524
 00336'020120
 00337'041040
 00340'052117
 00341'047524
 00342'020115
 00343'041440
 00344'041531
 00345'042514
 00346'020123
 00347'053040
 00350'041505
 00351'047524
 00352'020122
 00353'000000
      000353'         .LOC    .-1
 00353'106412 FRM0:   106412
 00354'177777         177777
 00355'020040 FRM2:   020040
 00356'020040         020040
 00357'020040         020040
 00360'020040         020040
 00361'000000         000000
                      .TXT    $    $
 00362'020040
 00363'020040
 00364'000000
                      .TXT    $    $
 00365'020040
 00366'020040
 00367'000000
                      .TXT    $    $
 00370'020040
 00371'020040
 00372'000000
 00373'020040         020040
 00374'106412         106412
 00375'177777         177777
              FRM3:   .TXT    $     PREVIOUS Z     $
 00376'020040
 00377'020040
 00400'050040
 00401'042522
 00402'044526
 00403'052517
 00404'020123
 00405'020132
 00406'020040
```

LISTING C21 (Continued)

```
0006  DUMP
 00407'020040
 00410'000000
       000410'          .LOC    .-1
                        .TXT    $  PREVIOUS DERIVATIVE $
 00410'020040
 00411'051120
 00412'053105
 00413'047511
 00414'051525
 00415'042040
 00416'051105
 00417'053111
 00420'052101
 00421'053111
 00422'020105
 00423'000000
       000423'          .LOC    .-1
                        .TXT    $  SIN(ANGLE)$
 00423'020040
 00424'044523
 00425'024116
 00426'047101
 00427'046107
 00430'024505
 00431'000000
       000431'          .LOC    .-1
 00431'106412           106412
 00432'177777           177777
 00433'000000 FRM4:     000000
 00434'020040           020040
 00435'000000           000000
 00436'020040           020040
 00437'000000           000000
 00440'106412           106412
 00441'177777           177777
              FRM5:     .TXT    $   PREVIOUS RANGE   $
 00442'020040
 00443'050040
 00444'042522
 00445'044526
 00446'052517
 00447'020123
 00450'040522
 00451'043516
 00452'020105
 00453'020040
 00454'000000
       000454'          .LOC    .-1
                        .TXT    $     TIME DELAY     $
 00454'020040
 00455'020040
 00456'052040
 00457'046511
 00460'020105
 00461'042504
 00462'040514
 00463'020131
 00464'020040
 00465'020040
```

LISTING C21 (Continued)

```
0007  DUMP
 00466'000000
       000466'          .LOC    ;-1
                        .TXT    $    GAIN$
 00466'020040
 00467'020040
 00470'040507
 00471'047111
 00472'000000
       000472'          .LOC    .-1
 00472'106412           106412
 00473'177777           177777
 00474'020040 FRM7;     020040
 00475'000000           000000
 00476'020040           020040
 00477'000000           000000
 00500'020040           020040
 00501'000000           000000
 00502'020040           020040
 00503'000000           000000
 00504'020040           020040
 00505'000000           000000
 00506'020040           020040
 00507'000000           000000
 00510'020040           020040
 00511'000000           000000
 00512'106412           106412
 00513'177777           177777
 00514'000000 FRM6;     000000
 00515'020040           020040
 00516'000000           000000
 00517'020040           020040
 00520'000000           000000
 00521'106412           106412
 00522'177777           177777
 00523'020040           020040
 00524'020040           020040
 00525'020040           020040
 00526'020040           020040
 00527'020040           020040
 00530'020040           020040
 00531'020040           020040
 00532'020040           020040
 00533'020040           020040
 00534'020040           020040
 00535'020040           020040
 00536'020040           020040
 00537'020040           020040
 00540'020040           020040
 00541'020040           020040
 00542'020040           020040
 00543'020040           020040
 00544'020040           020040
       000200 BLOX:     .BLK    200
                        .END
```

LISTING C21 (Continued)

FPMP SUBROUTINE

1. The FPMP subroutine is a group of floating point math routines which are required by the three layer ocean model programs.

2. GRADS, TSPP, ZLIM, MNMX, NRMD, NR1A2, NRLAB, FIN1, FIN2, FQ2, CPGN, SORT, CPHR, DSPRP, and TOTG

3.
```
            JSR@ .FFAD ; ADDITION
            (ADDRESS OF AUGEND)
            (ADDRESS OF ADDEND)
            (ADDRESS OF SUM)
      .
      .
      .
.FFAD:  FFAD
            JSR@ .FFSB ; SUBTRACTION
            (ADDRESS OF MINUEND)
            (ADDRESS OF SUBTRAHEND)
            (ADDRESS OF DIFFERENCE)
      .
      .
      .
.FFSB:  FFSB
```

```
        JSR@ .FFML ; MULTIPLICATION
        (ADDRESS OF MULTIPLICAND)
        (ADDRESS OF MULTIPLIER)
        (ADDRESS OR PRODUCT)
 .
 .
 .
.FFML:  FFML
        JSR@ .FFDV ; DIVISION
        (ADDRESS OF DIVIDEND)
        (ADDRESS OF DIVISOR)
        (ADDRESS OF QUOTIENT)
 .
 .
 .
.FFDV:  FFDV
        JSR@ .FFSQ ; SQUARE
        (ADDRESS OF ARGUMENT)
        (ADDRESS OF (ARGUMENT)^2)
 .
 .
 .
.FFSQ:  FFSQ
        JSR@ .FFSR ; SQUARE ROOT
        (ADDRESS OF ARGUMENT)
        (ADDRESS OF √ARGUMENT)
```

```
.
.
.
.FFSR:   FFSR
         JSR@ .FFLN ; NATURAL LOGARITHM
         (ADDRESS OF ARGUMENT)
         (ADDRESS OF LOG_e (ARGUMENT))
  .
  .
  .
 .FFLN:   FFLN
          JSR@ .FFLD ; FLOAT DOUBLE PRECISION NUMBER
          (ADDRESS OF FIXED POINT NUMBER)
          (BINARY POINT IN OCTAL)
          (ADDRESS OF FLOATING POINT NUMBER)
  .
  .
  .
 .FFLD:   FFLD
          JSR@ .FFXD ; FIX FLOATING POINT NUMBER TO DOUBLE
                       PRECISION NUMBER
          (ADDRESS OF FLOATING POINT NUMBER)
          (BINARY POINT IN OCTAL)
          (ADDRESS OF FIXED POINT NUMBER)
  .
  .
  .
 .FFXD:   FFXD
```

4. NONE

5. NONE

6. ----

7. ----

8. See Listing C22

9. The FPMP subroutine operates on three word floating binary point numbers. The first word is the exponent which uses 40000_8 as zero, 077777_8 as the maximum positive exponent, and 000001_8 as the maximum negative exponent. The second and third words make up the signed fractional part of the number.

```
0001  FPMP.

                        .NREL
                        .TITL   FPMP.P3 ; 03/14/75
                        .ENT    FFAD    ;FLOATING POINT ADD
                        .ENT    FFSB    ;FLOATING POINT SUBTRACT
                        .ENT    FFML    ;FLOATING POINT MULTIPLY
                        .ENT    FFDV    ;FLOATING POINT DIVIDE
                        .ENT    FFSQ    ;FLOATING POINT SQUARE
                        .ENT    FFSR    ;FLOATING POINT SQUARE ROOT
                        .ENT    FFLN    ;FLOATING POINT LOGRITHM(E)
                        .ENT    FFXD    ;DOUBLE FIX
                        .ENT    FFXS    ;SINGLE FIX
                        .ENT    FFLD    ;DOUBLE FLOAT
      000010            .RDX    8
                        ;JSR    FFAD    ;JSR FFSB
                        ;ADDEND         ;MINUEND
                        ;ADDER          ;SUBTRAHEND
                        ;SUM            ;DIFFERENCE
00000'031401 FFSB:      LDA     2,1,3   ;GET ADDRESS TO SUBTRAHEND, SCN
00001'021001            LDA     0,1,2   ;GET SCNH
00002'025002            LDA     1,2,2   ;GET SCNL
00003'124405            NEG     1,1,SNR ;CHANGE SIGN OF SUBTRAHEND
00004'100401            NEG     0,0,SKP
00005'100000            COM     0,0
00006'000407            JMP     AORS    ;GO SUBTRACT BY ADDING NEGATION
00007'171000 NOR1:      MOV     3,2     ;SAVE RETURN ADDRESS
00010'176000            ADC     3,3     ;GET -1 CORRECTION OF EXPONENT
                                        ;FOR SUM DUE TO /2.
00011'000476            JMP     NORM    ;GO NORMALIZE
00012'031401 FFAD:      LDA     2,1,3   ;GET ADDRESS TO ADDER, SCN
00013'021001            LDA     0,1,2   ;GET SCNH
00014'025002            LDA     1,2,2   ;GET SCNL
00015'040576 AORS:      STA     0,SCNH  ;SAVE D.P. SECOND ARGUMENT
00016'044576            STA     1,SCNL
00017'054576            STA     3,FRTN  ;SAVE RETURN ADDRESS
00020'035400            LDA     3,0,3   ;GET ADDRESS TO FIRST ARGUMENT, FRS
00021'021401            LDA     0,1,3   ;GET FRSH
00022'025402            LDA     1,2,3   ;GET FRSL
00023'040577            STA     0,FRSH  ;SAVE D.P. FIRST ARGUMENT, HIGH
00024'101005            MOV     0,0,SNR ;IS IT 0
00025'000527            JMP     STRS    ;YES, SO USE SCN AS SUM
00026'044575            STA     1,FRSL  ;SAVE D.P. FIRST ARGUMENT, LOW
00027'034564            LDA     3,SCNH  ;GET SCNH
00030'175005            MOV     3,3,SNR ;IS IT 0
00031'000515            JMP     STRF    ;YES, SO USE FRS AS SUM
00032'036563            LDA@    3,FRTN  ;GET FRS ADDRESS
00033'035400            LDA     3,0,3   ;GET FRSX, FRS EXPONENT
00034'031000            LDA     2,0,2   ;GET SCNX, SCN EXPONENT
00035'050564            STA     2,LEXP  ;SAVE POSSIBLE LARGEST EXPONENT
00036'172420            SUBZ    3,2     ;SCNX-FRSX
00037'151132            MOVZL#  2,2,SZC ;WHICH ARGUMENT TO BE R.S.
00040'000412            JMP     RSSC    ;R.S. SCN
00041'150405 RSFR:      NEG     2,2,SNR ;MAKE NEGATIVE COUNTER
00042'000424            JMP     DOAD1   ;NO SHIFT NEEDED, DO ADD
00043'034555            LDA     3,C31   ;GET 31, MAX RELEVANT DISTANCE
00044'173132            ADDZL#  3,2,SZC ;TOO MANY SHIFTS
00045'000505            JMP     STORS   ;YES, SO USE SCN AS RESULT
00046'101112            MOVL#   0,0,SZC ;DO POS, OR NEG, R.S.
00047'004470            JSR     NRSH    ;DO NEGATIVE R.S.
```

```
0002  FPMP.
 00050'004462          JSR     PRSH    ;DO POSITIVE R.S.
 00051'000415          JMP     DOAD1   ;DO ADDITION
 00052'054547 RSSC:    STA     3.LEXP  ;SAVE LARGEST EXPONENT
 00053'034545          LDA     3.C31   ;GET 31. MAX RELEVANT DISTANCE
 00054'173132          ADDZL#  3.2.SZC ;TOO MANY SHIFTS
 00055'000467          JMP     STORF   ;YES. SO USE FRS AS RESULT
 00056'020535          LDA     0.SCNH  ;GET SECOND ARGUMENT
 00057'024535          LDA     1.SCNL
 00060'101112          MOVL#   0.0.SZC ;DO POS. OR NEG. R.S.
 00061'004456          JSR     NRSH    ;DO NEGATIVE R.S.
 00062'004450          JSR     PRSH    ;DO POSITIVE R.S
 00063'030537          LDA     2.FRSH  ;GET MSB OF FIRST ARGUMENT
 00064'034537          LDA     3.FRSL
 00065'000403          JMP     DOAD2   ;DO ADDITION
 00066'030525 DOAD1:   LDA     2.SCNH  ;GET MSB OF SECOND ARGUMENT
 00067'034525          LDA     3.SCNL  ;GET LSB OF SECOND ARGUMENT
 00070'167220 DOAD2:   ADDZR   3.1     ;ADD LSB
 00071'176620          SUBZR   3.3     ;GET 100000
 00072'157400          AND     2.3     ;SAVE HOB OF SCN
 00073'117020          ADDZ    0.3     ;SET PROPER RESULT FOR CARRY
 00074'125122          MOVZL   1.1.SZC ;WAS THERE A CARRY
 00075'101404          INC     0.0.SZR ;IMPLEMENT CARRY
 00076'175101          MOVL    3.3.SKP ;SET SIGN CORRECTION
 00077'174100          COML    3.3     ;SIGN CORRECTION FOR 0
 00100'143200 PRNM:    ADDR    2.0     ;FORM SUM/2
 00101'125204          MOVR    1.1.SZR ;CHECK FOR 0
 00102'000403          JMP     OVRK    ;NOT ZERO
 00103'101005          MOV     0.0.SNR ;ARE BOTH 0
 00104'000453          JMP     FINP    ;SUM OF 0. SO TERMINATE
 00105'004702 OVRK:    JSR     NOR1    ;NORMALIZE
 00106'000454          JMP     FINS    ;TERMINATE SCALING
 00107'101112 NORM:    MOVL#   0.0.SZC ;POS. OR NEG. NORMALIZE
 00110'000404          JMP     NNRM    ;NEGATIVE NORMALIZE
 00111'103113 PNRM:    ADDL#   0.0.SNC ;BITS 0 AND 1 BOTH 0
 00112'000404          JMP     SCAL    ;YES. SO CONTINUE POS. NORMALIZE
 00113'001000          JMP     0.2     ;01 PATTERN. SO TERMINATE
 00114'103113 NNRM:    ADDL#   0.0.SNC ;BITS 0 AND 1 BOTH 1
 00115'000406          JMP     NCK     ;10 PATTERN. SO CHECK FOR
                                       ;ILLEGAL 2^31.
 00116'125100 SCAL:    MOVL    1.1     ;D.P. LEFT SHIFT
 00117'101100          MOVL    0.0
 00120'175402          INC     3.3.SZC ;BUMP NUMBER OF LEFT SHIFTS
 00121'101020          MOVZ    0.0     ;FORCE CARRY 0
 00122'000765          JMP     NORM    ;KEEP ON NORMALIZING
 00123'125004 NCK:     MOV     1.1.SZR ;CHECK FOR 0
 00124'001000          JMP     0.2     ;NOT 0. SO TERMINATE
 00125'101134          MOVZL#  0.0.SZR ;CHECK FOR 2^31
 00126'001000          JMP     0.2     ;FINALLY TERMINATE
 00127'101240          MOVOR   0.0     ;MAKE A LEGAL NUMBER
 00130'136000          ADC     1.3     ;REDUCE EXPONENT BY 1
 00131'001000          JMP     0.2     ;FINALLY TERMINATE
 00132'101220 PRSH:    MOVZR   0.0     ;POSITIVE RIGHT SHIFT
 00133'125200          MOVR    1.1
 00134'151404          INC     2.2.SZR ;SHIFTS COMPLETED
 00135'000775          JMP     PRSH    ;NO. CONTINUE SHIFTING
 00136'001400          JMP     0.3     ;YES. SO RETURN
 00137'101240 NRSH:    MOVOR   0.0     ;NEGATIVE RIGHT SHIFT
 00140'125200          MOVR    1.1
 00141'151404          INC     2.2.SZR ;SHIFTS COMPLETED
```

LISTING C22 (Continued)

```
0003  FPMP.
   00142'000775          JMP     NRSH    ;NO. CONTINUE SHIFTING
 00143'001401          JMP     1,3     ;YES. SO RETURN
 00144'020456 STORF:   LDA     0,FRSH  ;GET FIRST ARGUMENT
 00145'024456          LDA     1,FRSL
 00146'032447 STRF:    LDA@    2,FRTN  ;GET FIRST'S ADDRESS
 00147'031000 STO:     LDA     2,0,2   ;GET EXPONENT
 00150'155100 STOK:    MOVL    2,3     ;GET EXPONENT SIGN INTO CARRY
 00151'000415          JMP     FINU    ;STORE RESULT
 00152'030443 STORS:   LDA     2,FRTN  ;GET RETURN ADDRESS
 00153'031001          LDA     2,1,2   ;GET SECOND'S ADDRESS
 00154'020437 STRS:    LDA     0,SCNH  ;GET SECOND ARGUMENT
 00155'024437          LDA     1,SCNL
 00156'000771          JMP     STO     ;GET EXPONENT
 00157'101020 FINP:    MOVZ    0,0     ;SET CARRY ;Y0
 00160'000405          JMP     FINK    ;TERMINATE
 00161'176400 STOR:    SUB     3,3     ;GET 0 EXPONENT MODIFICATION
 00162'030437 FINS:    LDA     2,LEXP  ;GET EXPONENT FOR RESULT
 00163'172440          SUBO    3,2     ;MODIFY FOR NORMALIZATION
 00164'101021          MOVZ    0,0,SKP ;SET CARRY = 0
 00165'030437 FINK:    LDA     2,XS40  ;40000 FOR 0 RESULT
 00166'034427 FINU:    LDA     3,FRTN  ;GET RETURN ADDRESS
 00167'053402 FINE:    STA@    2,2,3   ;STORE EXPONENT OF RESULT
 00170'031402          LDA     2,2,3   ;GET ADDRESS OF RESULT
 00171'041001          STA     0,1,2   ;STORE DOUBLE PRECISION RESULT
 00172'045002          STA     1,2,2
 00173'001403          JMP     3,3     ;RETURN
                       ;JSR    FFSQ
                       ;ARGUMENT
                       ;SQUARE
 00174'054421 FFSQ:    STA     3,FRTN  ;SAVE RETURN ADDRESS, THEN MODIFY IT
 00175'014420          DSZ     FRTN    ;FOR TWO ARGUMENT CALLING SEQUENCE.
 00176'023400          LDA@    0,0,3   ;GET AB EXPONENT
 00177'030425          LDA     2,XS40  ;GET EXCESS 40000 MASK
 00200'142000          ADC     2,0     ;REMOVE 40001
 00201'101140          MOVOL   0,0     ;2*(EXPONENT-1)+1
 00202'143000          ADD     2,0     ;REINSERT 40000
 00203'040416          STA     0,LEXP  ;STORE EXPONENT OF SQUARE
 00204'050412          STA     2,SIGN  ;SET FOR POSITIVE RESULT
 00205'031400          LDA     2,0,3   ;GET ADDRESS OF ARGUMENT, AB
 00206'004526          JSR     DOUB    ;MAKE AB POSITIVE, AND DOUBLE
 00207'000756          JMP     FINK    ;0, SO SQUARE = 0, CARRY =0
 00210'044406          STA     1,SIGN  ;INSURE POSITIVE RESULT
 00211'006406          JSR@    .SQUR   ;SQUARE AB
 00212'000504          JMP     RETN    ;USE FMUL RETURN
 00213'000000 SCNH:    0
 00214'000000 SCNL:    0
 00215'000000 FRTN:    0
 00216'000000 SIGN:    0
 00217'000353',SQUR:   SQUR            ;VECTOR TO SQUR
 00220'000037 C31:     37
 00221'000000 LEXP:    0
 00222'000000 FRSH:    0
 00223'000000 FRSL:    0
 00224'040000 XS40:    40000
                       ;JSR    FFML    ;JSR FFDV
                       ;MULTIPLICAND   ;DIVIDEND
                       ;MULTIPLIER     ;DIVISOR
                       ;PRODUCT        ;QUOTIENT
 00225'102401 FFML:    SUB     0,0,SKP ;GET 0 FOR FLAG
```

LISTING C22 (Continued)

```
0004  FPMP.
 00226'102000 FFDV:   ADC     0.0      ;GET - 1 FOR FLAG
 00227'054766         STA     3 FRTN   ;SAVE RETURN ADDRESS
 00230'040763         STA     0.SCNH   ;SAVE FLAG
 00231'023400         LDA@    0.0.3    ;GET AB EXPONENT
 00232'027401         LDA@    1.1.3    ;GET CD EXPONENT
 00233'030771         LDA     2.XS40   ;GET EXCESS 40000 MASK
 00234'142400         SUB     2.0      ;REMOVE 40000
 00235'146000         ADC     2.1      ;REMOVE 40001
 00236'010755         ISZ     SCNH     ;MUL OR DIV
 00237'123001         ADD     1.0.SKP  ;ADD EXPONENTS FOR MUL
 00240'122000         ADC     1.0      ;SUBTRACT EXPONENTS FOR DIV
 00241'143000         ADD     2.0      ;REINSERT 40000
 00242'040757         STA     0.LEXP   ;STORE EXPONENT OF RESULT
 00243'050753         STA     2.SIGN   ;INITIALIZE SIGN OF RESULT
 00244'031401         LDA     2.1.3    ;GET ADDRESS OF CD
 00245'004467         JSR     DOUB     ;MAKE CD + DOUBLE. REMEMBER SIGN
 00246'000412         JMP     ILEG     ;ILLEGAL DIVIDE OR 0 MULTIPLY
 00247'040570         STA     0.C      ;SAVE C
 00250'044570         STA     1.D      ;SAVE D
 00251'032744         LDA@    2.FRTN   ;GET ADDRESS OF AB
 00252'004462         JSR     DOUB     ;MAKE AB + DOUBLE. REMEMBER SIGN
 00253'000712         JMP     FINK     ;0 RESULT. CARRY =0
 00254'014737         DSZ     SCNH     ;MUL OR DIV
 00255'000406         JMP     FDIVT    ;DO DOUBLE PRECISION DIVIDE
 00256'004525 FML1:   JSR     MULT     ;DO DOUBLE PRECISION MULTIPLY
 00257'000437         JMP     RETN     ;SETUP TO RETURN
 00260'014733 ILEG:   DSZ     SCNH     ;MUL OR DIV
 00261'105040         MOVO    0.1      ;CARRY =1 FOR ERROR: DIV
 00262'000703         JMP     FINK     ;0 RESULT
 00263'101220 FDIVT:  MOVZR   0.0      ;INSURE DIVISOR > DIVIDEND. AB
 00264'125200         MOVR    1.1
 00265'030552         LDA     2.C      ;GET C
 00266'073101         DIV              ;AB/C + REMAINDER
 00267'044733         STA     1.FRSH   ;SAVE MSB OF AB/C
 00270'126400         SUB     1.1      ;GET A 0
 00271'073101         DIV              ;REMAINDER /C
 00272'101002         MOV     0.0.SZC
 00273'000765         JMP     ILEG     ;ILLEGAL DIVIDE
 00274'044727         STA     1.FRSL   ;SAVE LSB OF AB/C
 00275'020725         LDA     0.FRSH   ;GET MSB OF AB/C
 00276'101220         MOVZR   0.0      ;SCALE TO INSURE LEGAL DIVIDE
 00277'125200         MOVR    1.1
 00300'073101         DIV              ;AB/C^2
 00301'101002         MOV     0.0.SZC
 00302'000756         JMP     ILEG     ;ILLEGAL DIVIDE
 00303'102400         SUB     0.0      ;GET ANOTHER 0
 00304'030534         LDA     2.D      ;GET D
 00305'073301         MUL              ;ABD/C^2
 00306'126400         SUB     1.1      ;GET A 0
 00307'115120         MOVZL   0.3      ;CORRECT FOR SCALING
 00310'131100         MOVL    1.2
 00311'020711         LDA     0.FRSH   ;GET DOUBLE PRECISION AB/C
 00312'024711         LDA     1.FRSL
 00313'166423         SUBZ    3.1.SNC  ;SUBTRACT LSB'S AND PROPOGATE
 00314'151400         INC     2.2      ;PROPOGATE THE CARRY
 00315'142420         SUBZ    2.0      ;THE OVERFLOW. AB/C - ABD/C^2.
 00316'034677 RETN:   LDA     3.FRTN   ;GET RETURN ADDRESS
 00317'030702         LDA     2.LEXP   ;GET EXPONENT ADDRESS
 00320'101133         MOVZL#  0.0.SNC  ;IS HOB OF RESULT A 1
```

LISTING C22 (Continued)

```
0005  FPMP.
 00321'000404           JMP     INSS    ;NO. SO JUST INSERT THE SIGN
 00322'151420           INCZ    2,2     ;YES. SO RIGHT SHIFT RESULT
                                        ;AND INCREMENT EXPONENT
 00323'101220 PRRS:     MOVZR   0,0     ;SHIFT RESULT RIGHT
 00324'125200           MOVR    1,1
 00325'034671 INSS:     LDA     3,SIGN  ;INSERT SIGN
 00326'175223           MOVZR   3,3,SNC ;PLUS OR MINUS
 00327'000621           JMP     STOK    ;LEAVE POSITIVE
 00330'124405           NEG     1,1,SNR ;MAKE RESULT NEGATIVE
 00331'100401           NEG     0,0,SKP
 00332'100000           COM     0,0
 00333'000615           JMP     STOK    ;GO RETURN
 00334'021001 DOUB:     LDA     0,1,2   ;GET MSB
 00335'025002           LDA     1,2,2   ;GET LSB
 00336'101133           MOVZL#  0,0,SNC ;POSITIVE OR NEGATIVE
 00337'000405           JMP     STR     ;POSITIVE
 00340'010656           ISZ     SIGN    ;SET SIGN FLAG
 00341'124405           NEG     1,1,SNR ;NEGATE
 00342'100401           NEG     0,0,SKP
 00343'100000           COM     0,0
 00344'125120 STR:      MOVZL   1,1     ;DOUBLE
 00345'101100           MOVL    0,0
 00346'040467           STA     0,A     ;STORE MSB
 00347'044467           STA     1,B     ;STORE LSB
 00350'101024           MOVZ    0,0,SZR ;IS IT 0
 00351'001401           JMP     1,3     ;RETURN
 00352'001400           JMP     0,3     ;0 RESULT
 00353'054641 SQUR:     STA     3,SCNL  ;SAVE RETURN ADDRESS
 00354'115000           MOV     0,3     ;SAVE A. B. IS IN AC1
 00355'040645           STA     0,FRSH  ;SAVE A AGAIN
 00356'102400           SUB     0,0     ;TRUNCATE THIS MULTIPLY
 00357'131000           MOV     1,2     ;B IN BOTH AC1 AND AC2
 00360'073301           MUL             ;BB
 00361'040642           STA     0,FRSL  ;SAVE MSB OF BB
 00362'102400           SUB     0,0     ;ROUND THIS MULTIPLY
 00363'165000           MOV     3,1     ;GET A
 00364'073301           MUL             ;THINK OF AB AS TRIPLE PRECISION
                                        ;HSB. MSB. LSB IN AC3. AC0. AND AC1.
 00365'176400           SUB     3,3     ;HSB = 0
 00366'125120           MOVZL   1,1     ;FORM 2AB AND PROPOGATE
 00367'101102           MOVL    0,0,SZC ;OVERFLOW UP THE LINE.
 00370'175400           INC     3,3
 00371'030632           LDA     2,FRSL  ;GET MSB OF BB
 00372'147023           ADDZ    2,1,SNC ;ADD LSB'S AND PROPOGATE OVERFLOW
 00373'000403           JMP     .+3     ;UP THE LINE.
 00374'101422           INCZ    0,0,SZC ;KEEP PROPOGATING
 00375'175400           INC     3,3
 00376'030624           LDA     2,FRSH  ;GET A
 00377'145000           MOV     2,1     ;GET A
 00400'073301 SQR1:     MUL             ;AA + MSB OF LESSER AFFECTS
 00401'163000           ADD     3,0     ;FORM DOUBLE PRECISION SQUARE
                                        ;IN AC0 AND AC1.
 00402'002612           JMP@    SCNL    ;RETURN
 00403'054611 MULT:     STA     3,SCNL  ;SAVE RETURN ADDRESS
 00404'024432           LDA     1,B     ;GET B
 00405'030433           LDA     2,D     ;GET D
 00406'102400           SUB     0,0     ;TRUNCATE THIS MULTIPLY
 00407'073301           MUL             ;DB
 00410'024425           LDA     1,A     ;GET A
```

LISTING C22 (Continued)

```
0006  FPMP.
 00411'073301          MUL             ;DA * MSB OF DB
 00412'044611          STA     1,FRSL  ;SAVE LSB OF TEMP. PRODUCT
 00413'040607          STA     0,FRSH  ;SAVE MSB OF TEMP. PRODUCT
 00414'102400          SUB     0,0     ;TRUNCATE THIS MULTIPLY
 00415'030422          LDA     2,C     ;GET C
 00416'024420          LDA     1,B     ;GET B
 00417'073301          MUL             ;THINK OF CB AS TRIPLE PRECISION.
                                       ;MSB, MSB, LSB, IN AC3, AC0, AND AC1.
 00420'176400          SUB     3,3     ;MSB = 0
 00421'030602          LDA     2,FRSL  ;GET LSB OF TEMP. PRODUCT
 00422'147023          ADDZ    2,1,SNC ;ADD LSB'S AND PROPOGATE OVERFLOW
 00423'000403          JMP     .+3     ;UP THE LINE.
 00424'101422          INCZ    0,0,SZC ;INCREMENT MSB
 00425'175400          INC     3,3     ;INCREMENT HSB
 00426'032406          LDA@    2,.FRSH ;GET MSB'S OF TEMP. PRODUCT
 00427'143022          ADDZ    2,0,SZC ;ADD MSB'S AND PROPOGATE OVERFLOW
 00430'175400          INC     3,3     ;TO THE HSB
 00431'024404          LDA     1,A     ;GET A, ADD IN LOWER AFFECTS
 00432'030405          LDA     2,C     ;GET C
 00433'000745          JMP     SQR1    ;FINSH WITHIN SQUR
 00434'000222'.FRSH:   FRSH
                A:
 00435'000000 XH:      0
                B:
 00436'000000 XL:      0
                C:
 00437'000000 X2H:     0
                D:
 00440'000000 X2L:     0
 00441'000000 AD1:     0
 00442'000000          0
 00443'000000          0
 00444'040001 AD3:     040001          ;2^1/2
 00445'055202          055202
 00446'074631          074631
 00447'040000 AD9:     040000          ;.59+
 00450'046253          046253
 00451'052427          052427
 00452'040000 AD8:     040000          ;.96+
 00453'075421          075421
 00454'074074          074074
 00455'040002 AD7:     040002          ;2.88+
 00456'056125          056125
 00457'020035          020035
 00460'040000 AD10:    040000          ;1/2
 00461'040000          040000
 00462'000000          000000
 00463'040000 AD14:    040000          ;.69315+
 00464'054271          054271
 00465'005773          005773
       000003 AD4:     .BLK    3
       000003 AD6:     .BLK    3
       000003 AD11:    .BLK    3
       000003 AD12:    .BLK    3
       000003 AD13:    .BLK    3
 00505'000000 SAVK:    0
 00506'000000 SAV1:    0
                       ;JSR    FFLN
                       ;ARGUMENT
```

LISTING C22 (Continued)

```
0007  FPMP.
                        ;LOGRITHM
00507'000000'.FFSB:     FFSB
00510'001127'.FFLD:     FFLD
00511'000225'.FFML:     FFML
00512'000174'.FFSQ:     FFSQ
00513'000226'.FFDV:     FFDV
00514'000012'.FFAD:     FFAD
00515'054551 FFLN:      STA     3,SRTN  ;SAVE RETURN ADDRESS THEN MODIFY IT
00516'020742            LDA     0,AD10
00517'040755            STA     0,AD11
00520'102400            SUB     0,0
00521'040754            STA     0,AD11+1
00522'040754            STA     0,AD11+2
00523'040762            STA     0,SAVK  ;ASSUME POSITIVE EXPONENT
00524'021401            LDA     0,1,3
00525'040522            STA     0,AD5
00526'014540            DSZ     SRTN    ;FOR TWO ARGUMENT CALLING SEQUENCE.
00527'023400            LDA@    0,0,3   ;GET ARGUMENT EXPONENT
00530'024535            LDA     1,XS4T  ;GET EXCESS 40000 MASK
00531'122000            ADC     1,0     ;FORM AB EXPONENT, BASE 2
00532'040754            STA     0,SAV1  ;SAVE AB EXPONENT
00533'101132            MOVZL#  0,0,SZC ;IS EXPONENT NEGATIVE
00534'014751            DSZ     SAVK    ;SET HOW = -1
00535'031400            LDA     2,0,3   ;GET ADDRESS OF ARGUMENT, AB
00536'021001            LDA     0,1,2   ;GET A
00537'025002            LDA     1,2,2   ;GET B
00540'101132            MOVZL#  0,0,SZC ;CHECK FOR ILLEGAL NEGATIVE ARGUMENT
00541'000516            JMP     ILER    ;ILLEGAL, SET CARRY = 1 AND
                                        ;RETURN 0 AS ANSWER.
00542'103113            ADDL#   0,0,SNC ;MUST BE ATLEAST .5 B31
00543'000514            JMP     ILER    ;ILLEGAL
00544'040671            STA     0,XH    ;SAVE X AS B31 FRACTION
00545'044671            STA     1,XL
00546'006742            JSR@    .FFLD
00547'000505'           SAVK
00550'000000            0
00551'000502'           AD13
00552'006736            JSR@    .FFLD
00553'000435'           XH
00554'000036            36
00555'000441'           AD1
00556'006731            JSR@    .FFSB
00557'000441'           AD1
00560'000444'           AD3
00561'000466'           AD4
00562'006732            JSR@    .FFAD
00563'000441'           AD1
00564'000444'           AD3
00565'000471'           AD6
00566'006725            JSR@    .FFDV
00567'000466'           AD4
00570'000471'           AD6
00571'000466'           AD4
00572'006720            JSR@    .FFSQ
00573'000466'           AD4
00574'000471'           AD6
00575'006714            JSR@    .FFML
00576'000466'           AD4
00577'000455'           AD7
```

LISTING C22 (Continued)

```
0008  FPMP.
  00600'000474'         AD11
  00601'006710          JSR@    .FFML
  00602'000471'         AD6
  00603'000452'         AD8
  00604'000477'         AD12
  00605'006704          JSR@    .FFML
  00606'000477'         AD12
  00607'000466'         AD4
  00610'000477'         AD12
  00611'006703          JSR@    .FFAD
  00612'000474'         AD11
  00613'000477'         AD12
  00614'000474'         AD11
  00615'006675          JSR@    .FFSQ
  00616'000471'         AD6
  00617'000471'         AD6
  00620'006671          JSR@    .FFML
  00621'000471'         AD6
  00622'000466'         AD4
  00623'000471'         AD6
  00624'006665          JSR@    .FFML
  00625'000471'         AD6
  00626'000447'         AD9
  00627'000471'         AD6
  00630'006664          JSR@    .FFAD
  00631'000471'         AD6
  00632'000474'         AD11
  00633'000474'         AD11
  00634'006660          JSR@    .FFAD
  00635'000474'         AD11
  00636'000460'         AD10
  00637'000474'         AD11
  00640'006654 SFLN:    JSR@    .FFAD
  00641'000474'         AD11
  00642'000502'         AD13
  00643'000474'         AD11
  00644'006645          JSR@    .FFML
  00645'000474'         AD11
  00646'000463'         AD14
  00647'000000 AD5:     0
  00650'034416          LDA     3,SRTN
  00651'001403          JMP     3,3
  00652'101020 FRC1:    MOVZ    0,0     ;SET CARRY = 0
  00653'034413 PC:      LDA     3,SRTN  ;GET RETURN ADDRESS
  00654'002401          JMP@    .FINE   ;GO STORE
  00655'000167'.FINE:   FINE            ;VECTOR TO FINE
  00656'000007'.NOR1:   NOR1            ;VECTOR TO NOR1
  00657'102400 ILER:    SUB     0,0
  00660'030405          LDA     2,XS4T  ;GET EXPONENT
  00661'105040          MOVO    0,1
  00662'000771          JMP     PC
  00663'030623 FRCE:    LDA     2,SAV1  ;GET EXPONENT
  00664'000766          JMP     FRC1    ;GO RETURN
  00665'040000 XS4T:    40000
  00666'000000 SRTN:    0
                        ;JSR    FFSR
                        ;ARGUMENT
                        ;SQUARE ROOT
  00667'054777 FFSR:    STA     3,SRTN  ;SAVE RETURN ADDRESS, THEN MODIFY IT
```

LISTING C22 (Continued)

```
0009  FPMP.
 00670'014776          DSZ     SRTN    ;FOR TWO ARGUMENT CALLING SEQUENCE.
 00671'030507          LDA     2,C8    ;GET AN 8
 00672'050512          STA     2,CONT  ;SET UP COUNTER
 00673'035400          LDA     3,0,3   ;GET ADDRESS TO ARGUMENT
 00674'021401          LDA     0,1,3   ;GET ARGUMENT HIGH
 00675'030770          LDA     2,XS4T  ;GET 40000
 00676'126420          SUBZ    1,1     ;GET A 0 IN CASE OF ERROR
                                       ;CARRY = 1.
 00677'101133          MOVZL#  0,0,SNC ;IS ARGUMENT NEGATIVE
 00700'101025          MOVZ    0,0,SNR ;IS ARGUMENT 0
 00701'000473          JMP     OVR1    ;YES SO RETURN WITH 0
 00702'025402          LDA     1,2,3   ;GET ARGUMENT LOW
 00703'035400          LDA     3,0,3   ;GET EXPONENT OF ARGUMENT
 00704'156400          SUB     2,3     ;REMOVE 40000
 00705'054475          STA     3,SAVH  ;SAVE EXPONENT OF ARGUMENT
 00706'175132          MOVZL#  3,3,SZC ;IS EXPONENT + OR -
 00707'175241          MOVOR   3,3,SKP ;RIGHT SHIFT -
 00710'175220          MOVZR   3,3     ;RIGHT SHIFT +
 00711'175002          MOV     3,3,SZC ;ODD OR EVEN
 00712'175400          INC     3,3     ;ODD SO MAKE X=X/2+1
 00713'157000          ADD     2,3     ;REINSERT 40000
 00714'054465          STA     3,SAVX  ;SAVE EXPONENT OF SQRT
 00715'034465          LDA     3,SAVH  ;GET EXPONENT OF ARGUMENT
 00716'175222          MOVZR   3,3,SZC ;WAS EXPONENT EVEN OR ODD
 00717'000404          JMP     ODD     ;ODD. SO RIGHT SHIFT ARGUMENT
                                       ;TWO POSITIONS AND USE .5B15
                                       ;AS ESTIMATE
 00720'115220          MOVZR   0,3     ;EVEN. SO RIGHT SHIFT ARGUMENT
                                       ;ONE POSITION AND USE
                                       ;(1+ARG)/2 B15 AS ESTIMATE.
 00721'173000          ADD     3,2     ;FORM ESTIMATE
 00722'000403          JMP     EVEN    ;SHIFT RIGHT ONCE
 00723'101220 ODD:     MOVZR   0,0     ;SHIFT RIGHT ONCE
 00724'125200          MOVR    1,1
 00725'176400 EVEN:    SUB     3,3     ;GET A 0
 00726'101220          MOVZR   0,0     ;SHIFT RIGHT ONCE
 00727'125200          MOVR    1,1
 00730'040455          STA     0,AA    ;SAVE ARGUMENT. DOUBLE PRECISION
 00731'044455          STA     1,BB
 00732'050455 LP:      STA     2,CC    ;SAVE ESTIMATE. DOUBLE PRECISION
 00733'054455          STA     3,DD
 00734'020451          LDA     0,AA    ;GET ARGUMENT
 00735'024451          LDA     1,BB
 00736'073101          DIV             ;AB/C + REMAINDER
 00737'044443          STA     1,SAVH  ;SAVE MSB OF AB/C
 00740'126400          SUB     1,1     ;GET A 0
 00741'073101          DIV             ;REMAINDER/C
 00742'044441          STA     1,SAVL  ;SAVE LSB OF AB/C
 00743'155000          MOV     2,3     ;KEEP C
 00744'102400          SUB     0,0     ;GET ANOTHER 0
 00745'024443          LDA     1,DD    ;GET D
 00746'131005          MOV     1,2,SNR ;IS D 0
 00747'000406          JMP     SHRT    ;YES. SO DO SHORT DIVIDE
 00750'030432          LDA     2,SAVH  ;GET MSB OF AB/C
 00751'073301          MUL             ;ABD/C
 00752'171000          MOV     3,2     ;GET C IN POSITION
 00753'073101          DIV             ;ABD/C^2
 00754'152520          SUBZL   2,2     ;GET A 1
 00755'135000 SHRT:    MOV     1,3     ;ABD/C^2
```

```
0010  FPMP.
 00756'020424          LDA     0,SAVH  ;GET DOUBLE PRECISION AB/C
 00757'024424          LDA     1,SAVL
 00760'166423          SUBZ    3,1,SNC ;SUBTRACT LSB'S AND PROPOGATE
 00761'142400          SUB     2,0     ;THE OVERFLOW. AB/C- ABD/C^2.
 00762'030425          LDA     2,CC    ;GET DOUBLE PRECISION ESTIMATE
 00763'034425          LDA     3,DD
 00764'167022          ADDZ    3,1,SZC ;FORM EST = ((ARG/EST)+EST)/2
 00765'101400          INC     0,0
 00766'113220          ADDZR   0,2     ;NEW ESTIMATE. DOUBLE PRECISION
 00767'135200          MOVR    1,3
 00770'014414          DSZ     CONT    ;DECREMENT COUNTER
 00771'000741          JMP     LP      ;CONTINUE SQUARE ROOTING
 00772'141000 OVER:    MOV     2,0     ;FINAL ESTIMATE = SQUARE ROOT
 00773'165021          MOVZ    3,1,SKP ;CARRY = 0
 00774'121001 OVR1:    MOV     1,0,SKP ;0 FOR ERROR OR 0. EXPONENT
 00775'030404          LDA     2,SAVX  ;GET EXPONENT OF SQRT
 00776'034670          LDA     3,SRTN  ;GET RETURN ADDRESS
 00777'002656 FNE:     JMPe    .FINE   ;GO STORE
 01000'000004 C8:      4
 01001'000000 SAVX:    0
 01002'000000 SAVH:    0
 01003'000000 SAVL:    0
 01004'000000 CONT:    0
 01005'000000 AA:      0
 01006'000000 BB:      0
 01007'000000 CC:      0
 01010'000000 DD:      0
                       ;JSR    FFXD    ;JSR FFXS
                       ;FLOAT          ;FLOAT
                       ;BPT            ;BPT
                       ;FIX            ;FIX
 01011'102521 FFXS:    SUBZL   0,0,SKP ;GET A 1
 01012'102400 FFXD:    SUB     0,0     ;GET A 0
 01013'040512          STA     0,FFER  ;CLEAR POSSIBLE ERRORS TO COME
 01014'040510          STA     0,DORS  ;SET DOUBLE OR SINGLE FLAG
 01015'054511          STA     3,XRTN  ;SAVE RETURN ADDRESS
 01016'027400          LDAe    1,0,3   ;GET EXPONENT (+40000) OF FLOAT
 01017'030502          LDA     2,CC31  ;GET 40031
 01020'132400          SUB     1,2     ;31-EXP
 01021'025401          LDA     1,1,3   ;GET BINARY POINT
 01022'132400          SUB     1,2     ;#SHIFT = 31-EXP-BPT
 01023'050500          STA     2,SAVS  ;SAVE SIGNED #SHIFTS
 01024'035400          LDA     3,0,3   ;GET ADDRESS TO FLOATED ARGUMENT
 01025'021401          LDA     0,1,3   ;GET MSB
 01026'025402          LDA     1,2,3   ;GET LSB
 01027'151025          MOVZ    2,2,SNR ;DO YOU NEED SHIFTING
 01030'000456          JMP     DOVR    ;NO.GO STORE FIXED
 01031'034471          LDA     3,C16   ;GET 16
 01032'151133          MOVZL#  2,2,SNC ;IS #SHIFTS POSITIVE
 01033'150400          NEG     2,2     ;MAKE #SHIFTS NEGATIVE
 01034'157026          ADDZ    2,3,SEZ ;16-#SHIFTS
 01035'000423          JMP     DQ0     ;Q=0, AC2 HAS -#SHIFTS
 01036'171005          MOV     3,2,SNR ;Q=1, AC2 HAS -SHIFTS
 01037'000404          JMP     DQ1     ;JUST 16 SHIFTS
 01040'034462          LDA     3,C16   ;GET 16
 01041'157023          ADDZ    2,3,SNC ;16-#SHIFTS
 01042'000413          JMP     DERR    ;TOO MANY SHIFTS, SO ERROR
 01043'034460 DQ1:     LDA     3,SAVS  ;GET SIGNED #SHIFTS
 01044'175132          MOVZL#  3,3,SZC ;LEFT OR RIGHT
```

LISTING C22 (Continued)

```
0011  FPMP.
 01045'000431          JMP     DQ1L     ;SHIFT LEFT
 01046'105000 DQ1R:    MOV     0.1      ;GET MSB INTO OLD LSB
 01047'102400          SUB     0.0      ;GET A ZERO
 01050'125132          MOVZL#  1.1.SZC  ;SIGN OF MSB
 01051'102000          ADC     0.0      ;NEGATIVE SIGN EXTENSION
 01052'151024          MOVZ    2.2.SZR  ;IS SHIFT NEEDED
 01053'000414          JMP     DQ0R     ;RIGHT SHIFT
 01054'000432          JMP     DOVR     ;NO SHIFT. GO STORE
 01055'126400 DERR:    SUB     1.1      ;ZERO RESULT
 01056'102420          SUBZ    0.0      ;CARRY =1
 01057'000427          JMP     DOVR     ;GO STORE FIXED
 01060'034443 DQ0:     LDA     3.SAVS   ;GET SIGNED #SHIFTS
 01061'175132          MOVZL#  3.3.SZC  ;LEFT OR RIGHT
 01062'000420          JMP     DQ0L     ;SHIFT LEFT
 01063'034441          LDA     3.DORS   ;GET DOUBLE OR SINGLE FLAG
 01064'175004          MOV     3.3.SZR  ;DOUBLE OR SINGLE
 01065'176000          ADC     3.3      ;GET -1 ERROR FLAG
 01066'054437          STA     3.FFER   ;ERROR HAS OCCURRED
 01067'101132 DQ0R:    MOVZL#  0.0.SZC  ;SIGN OF MSB. PLUS OR MINUS
 01070'101241          MOVOR   0.0.SKP  ;NEGATIVE RIGHT SHIFT
 01071'101220          MOVZR   0.0      ;DOUBLE PRECISION SIGNED
 01072'125200          MOVR    1.1      ;RIGHT SHIFT.
 01073'151444          INCO    2.2.SZR  ;CARRY =0
 01074'000773          JMP     DQ0R     ;CONTINUE SHIFTING
 01075'000411          JMP     DOVR     ;GO STORE
 01076'121000 DQ1L:    MOV     1.0      ;GET LSB INTO OLD MSB
 01077'126400          SUB     1.1      ;LSB =0
 01100'151045          MOVO    2.2.SNR  ;IS SHIFT. NEEDED
 01101'000405          JMP     DOVR     ;NO SHIFT. GO STORE
 01102'125120 DQ0L:    MOVZL   1.1      ;DOUBLE PRECISION LEFT SHIFT
 01103'101100          MOVL    0.0
 01104'151424          INCZ    2.2.SZR  ;CARRY=1
 01105'000775          JMP     DQ0L     ;CONTINUE SHIFTING
 01106'034417 DOVR:    LDA     3.FFER   ;GET ERROR FLAG
 01107'175100          MOVL    3.3      ;IF ERROR. SET CARRY = 1
 01110'034416          LDA     3.XRTN   ;GET RETURN ADDRESS
 01111'031402          LDA     2.2.3    ;GET ADDRESS TO FIXED
 01112'041000          STA     0.0.2    ;STORE MSB OF D.P.
 01113'020411          LDA     0.DORS   ;GET DOUBLE OR SINGLE FLAG
 01114'101004          MOV     0.0.SZR  ;DOUBLE OR SINGLE
 01115'045000          STA     1.0.2    ;SINGLE
 01116'101005          MOV     0.0.SNR  ;DOUBLE OR SINGLE
 01117'045001          STA     1.1.2    ;DOUBLE
 01120'001403          JMP     3.3      ;RETURN
 01121'040037 CC31:    040037
 01122'000020 C16:     000020
 01123'000000 SAVS:    0
 01124'000000 DORS:    0
 01125'000000 FFER:    0
 01126'000000 XRTN:    0
                       ;JSR    FFLD
                       ;FIX
                       ;BPT
                       ;FLOT
 01127'054777 FFLD:    STA     3.XRTN   ;SAVE RETURN ADDRESS
 01130'025401          LDA     1.1.3    ;GET BINARY POINT. BPT
 01131'030770          LDA     2.CC31   ;GET 40031
 01132'132400          SUB     1.2      ;FORM EXPONENT (+40000)
 01133'035400          LDA     3.0.3    ;GET ADDRESS TO FIX
```

LISTING C22 (Continued)

```
0012  FPMP.
 01134'021400          LDA     0.0.3   ;GET MSB OF DOUBLE PRECISION
 01135'025401          LDA     1.1.3   ;GET LSB OF DOUBLE PRECISION
 01136'176400          SUB     3.3     ;GET 0.FOR SHIFT COUNTER
 01137'101005          MOV     0.0.SNR ;CHECK FOR 0 FIX
 01140'125004          MOV     1.1.SZR
 01141'000403          JMP     NZRO    ;NOT ZERO SO LEFT JUSTIFY
                                       ;TO B31
 01142'152620          SUBZR   2.2     ;GET 100000 FOR 040000
 01143'000427          JMP     ZRO     ;ZERO. SO RETURN 0
 01144'125120 NZRO:    MOVZL   1.1     ;SHIFT TO FIND SIGN BIT
 01145'101102          MOVL    0.0.SZC
 01146'000407          JMP     SNEG    ;NEGATIVE. SCAN FOR 10
 01147'101132 SPOS:    MOVZL#  0.0.SZC ;POSITIVE. SCAN FOR 01
 01150'000417          JMP     COMP    ;01 FOUND
 01151'125120          MOVZL   1.1     ;LEFT JUSTIFY SOME MORE
 01152'101100          MOVL    0.0
 01153'175400          INC     3.3     ;BUMP SHIFT COUNTER
 01154'000773          JMP     SPOS    ;CONTINUE JUSTIFING
 01155'101133 SNEG:    MOVZL#  0.0.SNC ;NEGATIVE. SCAN FOR 10
 01156'000405          JMP     CKIL    ;10 FOUND
 01157'125120          MOVZL   1.1     ;LEFT JUSTIFY SOME MORE
 01160'101100          MOVL    0.0
 01161'175400          INC     3.3     ;BUMP SHIFT COUNTER
 01162'000773          JMP     SNEG    ;CONTINUE JUSTIFYING
 01163'101034 CKIL:    MOVZ#   0.0.SZR ;IS IT LEGAL
 01164'000403          JMP     COMP    ;YES. SO CONTINUE
 01165'125400          INC     1.1     ;NO. SO FORCE LEGAL
 01166'125400          INC     1.1
 01167'101200 COMP:    MOVR    0.0     ;RETURN TO B31
 01170'125200          MOVR    1.1
 01171'172401          SUB     3.2.SKP ;FORM EXP=EXP-#SHIFTS
 01172'151220 ZRO:     MOVZR   2.2     ;GET 40000 FOR EXPONENT
                                       ;OF ZERO RESULT.
 01173'101020          MOVZ    0.0     ;SET CARRY TO 0
 01174'034732          LDA     3.XRTN  ;GET RETURN ADDRESS
 01175'000602          JMP     FNE     ;GO STORE AND RETURN
                       .END
```

LISTING C22 (Continued)

APPENDIX D

Ocean Model Print-Out

Section 1 of this appendix shows a short display print out of the three layer ocean model in steps of 100 meters in horizontal range from 100 meters to 10 kilometers. Section 2 shows the same ocean model run in steps of 500 kilometers from 1 kilometer to 100 kilometers. Section 3 shows some of this same data in a long display format which presents more of the intermediate calculations and helps in understanding the operation of the program.

The short display gives the ray path type, the Newton-Raphson calculated horizontal range, the time delay, and gain for each ray path at a specified target-sonobuoy horizontal range. The value listed with the XX ray type is an average value of propagation gain in dB considering all the ray paths at the horizontal range preceding it. The long display gives additional information such as the derivative of the horizontal range with respect to z, the sine of the angle of arrival at the sonobuoy, and the value of z which the Newton-Raphson calculation found for the ray path.

SECTION 1

RAY T	PATH B	TYPE N	D	HORIZONTAL RANGE (METERS)	TIME DELAY (SECONDS)	GAIN (AMPLITUDE)
Ø.	4.	-Ø1.	Ø.	0000000100.003906	0000000.120605468	0.005540256
Ø.	4.	ØØ.	Ø.	0000000100.015624	0000005.160659790	0.000040602
Ø.	4.	ØØ.	1.	0000000100.000000	0000000.180297850	0.003714094
Ø.	4.	Ø1.	Ø.	0000000100.019530	0000005.428421020	0.000038620
Ø.	4.	Ø1.	1.	0000000100.015624	0000005.227706908	0.000040088
Ø.	4.	Ø2.	Ø.	0000000100.015624	0000010.488723754	0.000006320
Ø.	4.	Ø2.	1.	0000000100.019530	0000005.495468138	0.000038154
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Ø.	4.	ØØ.	1.	0000000200.000000	0000000.214370726	0.003123464
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Ø.	4.	Ø2.	Ø.	0000000200.035156	0000010.488723754	0.000006320
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Ø.	4.	ØØ.	Ø.	0000000299.988280	0000005.164672850	0.000040570
Ø.	4.	ØØ.	1.	0000000300.011718	0000000.261489868	0.002560440
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Ø.	4.	Ø2.	Ø.	0000000300.000000	0000010.488723754	0.000006322
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Ø.	4.	-Ø1.	Ø.	0000000400.000000	0000000.285812376	0.002323288
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Ø.	4.	Ø1.	Ø.	0000000400.085936	0000005.434921264	0.000038568
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Ø.	4.	Ø2.	Ø.	0000000400.066406	0000010.492858886	0.000006318
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Ø.	4.	-Ø1.	Ø.	0000000500.003906	0000000.349243164	0.001894102
Ø.	4.	ØØ.	Ø.	0000000500.003906	0000005.171447752	0.000040514
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Ø.	4.	Ø1.	Ø.	0000000500.011718	0000005.438568114	0.000038542
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Ø.	4.	Ø2.	Ø.	0000000599.972656	0000010.496704100	0.000006316
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X.	X.	00.	0.	0000000000.000000	-0000068.857864378	0.000000000
0.	3.	-01.	0.	0000003200.000000	0000002.143157958	0.000200370
0.	3.	00.	1.	0000003200.000000	0000002.149063110	0.000270680
0.	4.	00.	0.	0000003200.000000	0000005.583236694	0.000037488
0.	4.	01.	0.	0000003199.996092	0000005.831832884	0.000035914
0.	4.	01.	1.	0000003199.996092	0000005.645339964	0.000037084
0.	4.	02.	0.	0000003200.000000	0000010.703002928	0.000006192

0.	4.	02.	1.	0000003200.000000	0000005.894363402	0.000035540
X.	X.	00.	0.	0000000000.000000	-0000069.252410888	0.000000000
0.	3.	-01.	0.	0000003300.000000	0000002.209976196	0.000188302
0.	3.	00.	1.	0000003300.101562	0000002.215866088	0.000260142
0.	4.	00.	0.	0000003300.000000	0000005.608993530	0.000037314
0.	4.	01.	0.	0000003299.996092	0000005.856506346	0.000035760
0.	4.	01.	1.	0000003299.996092	0000005.670806884	0.000036916
0.	4.	02.	0.	0000003300.000000	0000010.716445922	0.000006184
0.	4.	02.	1.	0000003300.000000	0000005.918762206	0.000035392
X.	X.	00.	0.	0000000000.000000	-0000069.647552490	0.000000000
0.	3.	-01.	0.	0000003400.000000	0000002.276809692	0.000176802
0.	3.	00.	1.	0000003400.062500	0000002.282608032	0.000249944
0.	4.	00.	0.	0000003400.000000	0000005.635406494	0.000037136
0.	4.	01.	0.	0000003399.996092	0000005.881820678	0.000035604
0.	4.	01.	1.	0000003399.996092	0000005.696945190	0.000036744
0.	4.	02.	0.	0000003399.996092	0000010.730331420	0.000006176
0.	4.	02.	1.	0000003400.000000	0000005.943832396	0.000035240
X.	X.	00.	0.	0000000000.000000	-0000070.043426512	0.000000000
0.	3.	-01.	0.	0000003500.000000	0000002.343627928	0.000165810
0.	3.	00.	1.	0000003500.042968	0000002.349349974	0.000240048
0.	4.	00.	0.	0000003499.996092	0000005.662490844	0.000036956
0.	4.	01.	0.	0000003499.996092	0000005.907791136	0.000035446
0.	4.	01.	1.	0000003499.996092	0000005.723739624	0.000036570
0.	4.	02.	0.	0000003499.996092	0000010.744552612	0.000006168
0.	4.	02.	1.	0000003499.996092	0000005.969528198	0.000035086
X.	X.	00.	0.	0000000000.000000	-0000070.441055296	0.000000000
0.	3.	-01.	0.	0000003600.000000	0000002.410461424	0.000155278
0.	3.	00.	1.	0000003600.027342	0000002.416107176	0.000230440
0.	4.	00.	0.	0000003599.996092	0000005.690216064	0.000036774
0.	4.	01.	0.	0000003600.000000	0000005.934387206	0.000035284
0.	4.	01.	1.	0000003599.996092	0000005.751190184	0.000036392
0.	4.	02.	0.	0000003599.996092	0000010.759216308	0.000006160
0.	4.	02.	1.	0000003599.996092	0000005.995849608	0.000034932
X.	X.	00.	0.	0000000000.000000	-0000070.841140746	0.000000000
0.	3.	-01.	0.	0000003700.000000	0000002.477294920	0.000145154
0.	3.	00.	1.	0000003700.015624	0000002.482879638	0.000221106
0.	4.	00.	0.	0000003700.000000	0000005.718597412	0.000036588
0.	4.	01.	0.	0000003700.000000	0000005.961608886	0.000035122
0.	4.	01.	1.	0000003699.996092	0000005.779266356	0.000036214
0.	4.	02.	0.	0000003700.000000	0000010.774246214	0.000006150
0.	4.	02.	1.	0000003699.996092	0000006.022796630	0.000034772
X.	X.	00.	0.	0000000000.000000	-0000071.244384764	0.000000000
0.	3.	-01.	0.	0000003800.117186	0000002.544204710	0.000135382
0.	3.	00.	1.	0000003800.007812	0000002.549667358	0.000212026
0.	4.	00.	0.	0000003800.000000	0000005.747589110	0.000036402
0.	4.	01.	0.	0000003799.996092	0000005.989440916	0.000034956
0.	4.	01.	1.	0000003800.000000	0000005.807968138	0.000036032
0.	4.	02.	0.	0000003800.000000	0000010.789672850	0.000006142
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X.	X.	00.	0.	0000000000.000000	-0000071.651809692	0.000000000
0.	3.	-01.	0.	0000003900.078124	0000002.611007690	0.000125938
0.	3.	00.	1.	0000003900.003906	0000002.616455078	0.000203190
0.	4.	00.	0.	0000003899.996092	0000005.777221678	0.000036212
0.	4.	01.	0.	0000003900.000000	0000006.017898558	0.000034788
0.	4.	01.	1.	0000003900.000000	0000005.837295532	0.000035848
0.	4.	02.	0.	0000003899.996092	0000010.805480956	0.000006132
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X.	X.	00.	0.	0000000000.000000	-0000072.063735960	0.000000000
0.	3.	-01.	0.	0000004000.039062	0000002.677825926	0.000116766
0.	3.	00.	1.	0000004000.003906	0000002.683258056	0.000194582
0.	4.	00.	0.	0000004000.113280	0000005.807479858	0.000036020
0.	4.	01.	0.	0000004000.000000	0000006.046951292	0.000034620
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0.	4.	02.	0.	0000004000.109374	0000010.821670532	0.000006124
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X.	X.	00.	0.	0000000000.000000	-0000072.481353758	0.000000000

Ø.	3.	-Ø1.	Ø.	0000004100.023436	0000002.744659422	0.000107810
Ø.	3.	ØØ.	1.	0000004100.000000	0000002.750045776	0.000186190
Ø.	4.	ØØ.	Ø.	0000004100.089842	0000005.838517870	0.000035828
Ø.	4.	Ø1.	Ø.	0000004100.113280	0000006.076614378	0.000034448
Ø.	4.	Ø1.	1.	0000004100.097656	0000005.897781372	0.000035474
Ø.	4.	Ø2.	Ø.	0000004100.085936	0000010.838256836	0.000006114
Ø.	4.	Ø2.	1.	0000004100.121092	0000006.136688232	0.000034118
X.	X.	ØØ.	Ø.	0000000000.000000	-0000072.905670166	0.000000000
Ø.	3.	-Ø1.	Ø.	0000004200.011718	0000002.811492918	0.000099022
Ø.	3.	ØØ.	1.	0000004200.003906	0000002.816864012	0.000178002
Ø.	4.	ØØ.	Ø.	0000004200.070312	0000005.869735716	0.000035634
Ø.	4.	Ø1.	Ø.	0000004200.089842	0000006.106826782	0.000034276
Ø.	4.	Ø1.	1.	0000004200.074218	0000005.928894042	0.000035286
Ø.	4.	Ø2.	Ø.	0000004200.066406	0000010.855255126	0.000006104
Ø.	4.	Ø2.	1.	0000004200.097656	0000006.166610716	0.000033950
X.	X.	ØØ.	Ø.	0000000000.000000	-0000073.337738036	0.000000000
Ø.	3.	-Ø1.	Ø.	0000004300.007812	0000002.878326416	0.000090340
Ø.	3.	ØØ.	1.	0000004300.000000	0000002.883666992	0.000170006
Ø.	4.	ØØ.	Ø.	0000004300.054686	0000005.901763916	0.000035436
Ø.	4.	Ø1.	Ø.	0000004300.074218	0000006.137619018	0.000034102
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Ø.	4.	Ø2.	Ø.	0000004300.050780	0000010.872589110	0.000006094
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Ø.	4.	Ø1.	Ø.	0000004400.054686	0000006.168975830	0.000033926
Ø.	4.	Ø1.	1.	0000004400.046874	0000005.992874144	0.000034904
Ø.	4.	Ø2.	Ø.	0000004400.042968	0000010.890335082	0.000006084
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X.	X.	ØØ.	Ø.	0000000000.000000	-0000074.230117796	0.000000000
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Ø.	4.	Ø2.	1.	0000004500.046874	0000006.259780882	0.000033438
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Ø.	3.	-Ø1.	Ø.	0000004600.000000	0000003.078857420	0.000064098
Ø.	3.	ØØ.	1.	0000004600.000000	0000003.084136962	0.000147046
Ø.	4.	ØØ.	Ø.	0000004600.027342	0000006.001205444	0.000034840
Ø.	4.	Ø1.	Ø.	0000004600.035156	0000006.233352660	0.000033570
Ø.	4.	Ø1.	1.	0000004600.027342	0000006.059097290	0.000034516
Ø.	4.	Ø2.	Ø.	0000004600.027342	0000010.926895140	0.000006064
Ø.	4.	Ø2.	1.	0000004600.039062	0000006.291946410	0.000033264
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Ø.	3.	-Ø1.	Ø.	0000004700.011718	0000003.145706176	0.000054812
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Ø.	4.	Ø1.	Ø.	0000004700.027342	0000006.266357420	0.000033590
Ø.	4.	Ø1.	1.	0000004700.023436	0000006.093032836	0.000034322
Ø.	4.	Ø2.	Ø.	0000004700.015624	0000010.945724486	0.000006054
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Ø.	3.	-Ø1.	Ø.	0000004800.066406	0000003.212585448	0.000044762
Ø.	3.	ØØ.	1.	0000004800.003906	0000003.217788696	0.000132480
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Ø.	4.	Ø2.	Ø.	0000004800.015624	0000010.964981078	0.000006042
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0.	4.	00.	0.	0000004900.011718	0000006.105575560	0.000034236
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0.	4.	01.	1.	0000004900.011718	0000006.162506102	0.000033928
0.	4.	02.	0.	0000004900.011718	0000010.984573364	0.000006032
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X.	X.	00.	0.	0000000000.000000	-0000076.707809448	0.000000000
0.	3.	-01.	0.	0000005000.109374	0000003.346298216	0.000016648
0.	3.	00.	1.	0000005000.121092	0000003.351531982	0.000118580
0.	4.	00.	0.	0000005000.007812	0000006.141418456	0.000034032
0.	4.	01.	0.	0000005000.011718	0000006.368530272	0.000032846
0.	4.	01.	1.	0000005000.007812	0000006.198013304	0.000033750
0.	4.	02.	0.	0000005000.007812	0000011.004547118	0.000006020
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X.	X.	00.	0.	0000000000.000000	-0000077.267196654	0.000000000
0.	3.	00.	1.	0000005100.082030	0000003.418334960	0.000111476
0.	4.	00.	0.	0000005100.003906	0000006.177764892	0.000033828
0.	4.	01.	0.	0000005100.011718	0000006.403594970	0.000032664
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X.	X.	00.	0.	0000000000.000000	-0000077.734664916	0.000000000
0.	3.	00.	1.	0000005200.050780	0000003.485153198	0.000104644
0.	4.	00.	0.	0000005200.003906	0000006.214614868	0.000033624
0.	4.	01.	0.	0000005200.007812	0000006.439178466	0.000032480
0.	4.	01.	1.	0000005200.003906	0000006.270568846	0.000033334
0.	4.	02.	0.	0000005200.003906	0000011.045562744	0.000005998
0.	4.	02.	1.	0000005200.007812	0000006.495956420	0.000032204
X.	X.	00.	0.	0000000000.000000	-0000078.147415160	0.000000000
0.	3.	00.	1.	0000005300.027342	0000003.551971434	0.000097858
0.	4.	00.	0.	0000005300.003906	0000006.251953124	0.000033420
0.	4.	01.	0.	0000005300.003906	0000006.475234984	0.000032296
0.	4.	01.	1.	0000005300.003906	0000006.307586668	0.000033134
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0.	4.	00.	0.	0000005500.000000	0000006.328079222	0.000033010
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0.	4.	01.	1.	0000005800.000000	0000006.499755858	0.000032138
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0.	4.	00.	0.	0000005900.000000	0000006.485870360	0.000032192
0.	4.	01.	0.	0000005900.000000	0000006.701477050	0.000031188
0.	4.	01.	1.	0000005900.000000	0000006.539535522	0.000031938
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0.	4.	00.	0.	0000006000.000000	0000006.526412962	0.000031988
0.	4.	01.	0.	0000006000.000000	0000006.740737914	0.000031004
0.	4.	01.	1.	0000006000.000000	0000006.579772948	0.000031740
0.	4.	02.	0.	0000006000.000000	0000011.223999022	0.000005900
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X.	X.	00.	0.	0000000000.000000	-0000081.993591308	0.000000000
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0.	4.	00.	0.	0000006100.000000	0000006.567382812	0.000031786
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X.	X.	00.	0.	0000000000.000000	-0000082.582992552	0.000000000
0.	3.	00.	1.	0000006200.031250	0000004.153564452	0.000029924
0.	4.	00.	0.	0000006200.000000	0000006.608764648	0.000031582
0.	4.	01.	0.	0000006200.000000	0000006.820556640	0.000030634
0.	4.	01.	1.	0000006200.000000	0000006.661483764	0.000031344
0.	4.	02.	0.	0000006200.000000	0000011.272094726	0.000005876
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X.	X.	00.	0.	0000000000.000000	-0000083.212203978	0.000000000
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0.	4.	00.	0.	0000006300.000000	0000006.650573730	0.000031380
0.	4.	01.	0.	0000006300.000000	0000006.861083984	0.000030450
0.	4.	01.	1.	0000006300.000000	0000006.702957152	0.000031146
0.	4.	02.	0.	0000006300.000000	0000011.296661376	0.000005862
0.	4.	02.	1.	0000006300.000000	0000006.914459228	0.000030224
X.	X.	00.	0.	0000000000.000000	-0000083.891220092	0.000000000
0.	4.	00.	0.	0000006400.000000	0000006.692764282	0.000031178
0.	4.	01.	0.	0000006400.000000	0000006.902023314	0.000030266
0.	4.	01.	1.	0000006400.000000	0000006.744842528	0.000030948
0.	4.	02.	0.	0000006399.996092	0000011.321563720	0.000005850
0.	4.	02.	1.	0000006400.000000	0000006.955093382	0.000030044
X.	X.	00.	0.	0000000000.000000	-0000084.221649168	0.000000000
0.	4.	00.	0.	0000006500.000000	0000006.735351562	0.000030978
0.	4.	01.	0.	0000006499.996092	0000006.943359374	0.000030082
0.	4.	01.	1.	0000006500.000000	0000006.787109374	0.000030752
0.	4.	02.	0.	0000006500.000000	0000011.346786498	0.000005836
0.	4.	02.	1.	0000006500.000000	0000006.996109008	0.000029864
X.	X.	00.	0.	0000000000.000000	-0000084.275482176	0.000000000
0.	4.	00.	0.	0000006600.000000	0000006.778335570	0.000030778
0.	4.	01.	0.	0000006600.000000	0000006.985076904	0.000029900
0.	4.	01.	1.	0000006600.000000	0000006.829772948	0.000030556
0.	4.	02.	0.	0000006599.996092	0000011.372344970	0.000005824
0.	4.	02.	1.	0000006600.000000	0000007.037536620	0.000029686
X.	X.	00.	0.	0000000000.000000	-0000084.329498290	0.000000000
0.	4.	00.	0.	0000006700.000000	0000006.821701048	0.000030578
0.	4.	01.	0.	0000006700.000000	0000007.027175902	0.000029716
0.	4.	01.	1.	0000006700.000000	0000006.872817992	0.000030362
0.	4.	02.	0.	0000006700.000000	0000011.398254394	0.000005810
0.	4.	02.	1.	0000006700.000000	0000007.079330444	0.000029508
X.	X.	00.	0.	0000000000.000000	-0000084.383682250	0.000000000
0.	4.	00.	0.	0000006800.000000	0000006.865417480	0.000030378
0.	4.	01.	0.	0000006800.000000	0000007.069656372	0.000029534
0.	4.	01.	1.	0000006799.996092	0000006.916229248	0.000030166

0.	4.	02.	0.	0000006799.996092	0000011.424484252	0.000005796
0.	4.	02.	1.	0000006800.000000	0000007.121505736	0.000029330
X.	X.	00.	0.	0000000000.000000	-0000084.438018798	0.000000000
0.	4.	00.	0.	0000006900.000000	0000006.909515380	0.000030180
0.	4.	01.	0.	0000006900.000000	0000007.112518310	0.000029354
0.	4.	01.	1.	0000006900.000000	0000006.960006712	0.000029972
0.	4.	02.	0.	0000006900.000000	0000011.451049804	0.000005782
0.	4.	02.	1.	0000006900.000000	0000007.164047240	0.000029152
X.	X.	00.	0.	0000000000.000000	-0000084.492492674	0.000000000
0.	4.	00.	0.	0000006999.996092	0000006.953964232	0.000029984
0.	4.	01.	0.	0000007000.000000	0000007.155751200	0.000029172
0.	4.	01.	1.	0000007000.000000	0000007.004150390	0.000029780
0.	4.	02.	0.	0000006999.996092	0000011.477935790	0.000005768
0.	4.	02.	1.	0000007000.000000	0000007.206970214	0.000028974
X.	X.	00.	0.	0000000000.000000	-0000084.547088622	0.000000000
0.	4.	00.	0.	0000007100.000000	0000006.998779296	0.000029788
0.	4.	01.	0.	0000007099.996092	0000007.199295042	0.000028992
0.	4.	01.	1.	0000007100.000000	0000007.048629760	0.000029588
0.	4.	02.	0.	0000007100.000000	0000011.505142210	0.000005754
0.	4.	02.	1.	0000007100.000000	0000007.250228880	0.000028798
X.	X.	00.	0.	0000000000.000000	-0000084.601806640	0.000000000
0.	4.	00.	0.	0000007199.996092	0000007.043914794	0.000029592
0.	4.	01.	0.	0000007199.996092	0000007.243225096	0.000028814
0.	4.	01.	1.	0000007199.996092	0000007.093475340	0.000029398
0.	4.	02.	0.	0000007200.000000	0000011.532669066	0.000005742
0.	4.	02.	1.	0000007200.000000	0000007.293853758	0.000028622
X.	X.	00.	0.	0000000000.000000	-0000084.656631468	0.000000000
0.	4.	00.	0.	0000007299.996092	0000007.089401244	0.000029398
0.	4.	01.	0.	0000007299.996092	0000007.287475584	0.000028634
0.	4.	01.	1.	0000007300.000000	0000007.138656616	0.000029206
0.	4.	02.	0.	0000007299.996092	0000011.560516356	0.000005726
0.	4.	02.	1.	0000007300.000000	0000007.337814330	0.000028448
X.	X.	00.	0.	0000000000.000000	-0000084.711532592	0.000000000
0.	4.	00.	0.	0000007400.000000	0000007.135223388	0.000029206
0.	4.	01.	0.	0000007400.000000	0000007.332092284	0.000028456
0.	4.	01.	1.	0000007400.000000	0000007.184158324	0.000029018
0.	4.	02.	0.	0000007399.996092	0000011.588668822	0.000005712
0.	4.	02.	1.	0000007399.996092	0000007.382125854	0.000028274
X.	X.	00.	0.	0000000000.000000	-0000084.766525268	0.000000000
0.	4.	00.	0.	0000007499.996092	0000007.181365966	0.000029014
0.	4.	01.	0.	0000007500.000000	0000007.377014160	0.000028280
0.	4.	01.	1.	0000007500.000000	0000007.229995726	0.000028830
0.	4.	02.	0.	0000007499.996092	0000011.617141722	0.000005698
0.	4.	02.	1.	0000007500.000000	0000007.426757812	0.000028100
X.	X.	00.	0.	0000000000.000000	-0000084.821594238	0.000000000
0.	4.	00.	0.	0000007599.996092	0000007.227828978	0.000028822
0.	4.	01.	0.	0000007599.996092	0000007.422271728	0.000028104
0.	4.	01.	1.	0000007600.000000	0000007.276153564	0.000028642
0.	4.	02.	0.	0000007599.996092	0000011.645935058	0.000005684
0.	4.	02.	1.	0000007599.996092	0000007.471725462	0.000027928
X.	X.	00.	0.	0000000000.000000	-0000084.876724242	0.000000000
0.	4.	00.	0.	0000007700.000000	0000007.274597166	0.000028632
0.	4.	01.	0.	0000007700.000000	0000007.467864990	0.000027928
0.	4.	01.	1.	0000007700.000000	0000007.322631834	0.000028456
0.	4.	02.	0.	0000007700.000000	0000011.675033568	0.000005670
0.	4.	02.	1.	0000007700.000000	0000007.517013548	0.000027756
X.	X.	00.	0.	0000000000.000000	-0000084.931900024	0.000000000
0.	4.	00.	0.	0000007800.000000	0000007.321685790	0.000028444
0.	4.	01.	0.	0000007799.996092	0000007.513748168	0.000027754
0.	4.	01.	1.	0000007800.000000	0000007.369415282	0.000028272
0.	4.	02.	0.	0000007799.996092	0000011.704437254	0.000005656
0.	4.	02.	1.	0000007800.000000	0000007.562622070	0.000027584
X.	X.	00.	0.	0000000000.000000	-0000084.987106322	0.000000000
0.	4.	00.	0.	0000007900.000000	0000007.369064330	0.000028256
0.	4.	01.	0.	0000007900.000000	0000007.559951782	0.000027580
0.	4.	01.	1.	0000007900.000000	0000007.416503906	0.000028088

0.	4.	02.	0.	0000007900.000000	0000011.734130858	0.000005640
0.	4.	02.	1.	0000007899.996092	0000007.608535766	0.000027414
X.	X.	00.	0.	0000000000.000000	-0000085.042358398	0.000000000
0.	4.	00.	0.	0000007999.996092	0000007.416732788	0.000028070
0.	4.	01.	0.	0000008000.000000	0000007.606460570	0.000027408
0.	4.	01.	1.	0000008000.000000	0000007.463882446	0.000027906
0.	4.	02.	0.	0000007999.996092	0000011.764144896	0.000005626
0.	4.	02.	1.	0000008000.000000	0000007.654739378	0.000027244
X.	X.	00.	0.	0000000000.000000	-0000085.097625732	0.000000000
0.	4.	00.	0.	0000008099.996092	0000007.464706420	0.000027886
0.	4.	01.	0.	0000008100.000000	0000007.653259276	0.000027236
0.	4.	01.	1.	0000008099.996092	0000007.511550902	0.000027724
0.	4.	02.	0.	0000008100.000000	0000011.794433592	0.000005612
0.	4.	02.	1.	0000008100.000000	0000007.701263426	0.000027078
X.	X.	00.	0.	0000000000.000000	-0000085.152908324	0.000000000
0.	4.	00.	0.	0000008200.000000	0000007.512954710	0.000027702
0.	4.	01.	0.	0000008200.000000	0000007.700347900	0.000027066
0.	4.	01.	1.	0000008200.000000	0000007.559509276	0.000027542
0.	4.	02.	0.	0000008199.996092	0000011.825042724	0.000005598
0.	4.	02.	1.	0000008200.000000	0000007.748062132	0.000026910
X.	X.	00.	0.	0000000000.000000	-0000085.208206176	0.000000000
0.	4.	00.	0.	0000008300.113280	0000007.561538696	0.000027520
0.	4.	01.	0.	0000008300.000000	0000007.747726440	0.000026896
0.	4.	01.	1.	0000008299.996092	0000007.607742308	0.000027364
0.	4.	02.	0.	0000008299.996092	0000011.855941772	0.000005582
0.	4.	02.	1.	0000008299.996092	0000007.795166014	0.000026744
X.	X.	00.	0.	0000000000.000000	-0000085.263504028	0.000000000
0.	4.	00.	0.	0000008400.101562	0000007.610336302	0.000027338
0.	4.	01.	0.	0000008399.996092	0000007.795379638	0.000026728
0.	4.	01.	1.	0000008400.109374	0000007.656326292	0.000027186
0.	4.	02.	0.	0000008400.000000	0000011.887130756	0.000005568
0.	4.	02.	1.	0000008399.996092	0000007.842544554	0.000026578
X.	X.	00.	0.	0000000000.000000	-0000085.318801878	0.000000000
0.	4.	00.	0.	0000008500.089842	0000007.659393310	0.000027158
0.	4.	01.	0.	0000008500.121092	0000007.843383788	0.000026562
0.	4.	01.	1.	0000008500.093750	0000007.705093382	0.000027010
0.	4.	02.	0.	0000008500.000000	0000011.918624876	0.000005552
0.	4.	02.	1.	0000008499.996092	0000007.890197752	0.000026414
X.	X.	00.	0.	0000000000.000000	-0000085.374084472	0.000000000
0.	4.	00.	0.	0000008600.078124	0000007.708724974	0.000026980
0.	4.	01.	0.	0000008600.105468	0000007.891586302	0.000026394
0.	4.	01.	1.	0000008600.082030	0000007.754135130	0.000026834
0.	4.	02.	0.	0000008600.000000	0000011.950378416	0.000005538
0.	4.	02.	1.	0000008600.113280	0000007.938186644	0.000026250
X.	X.	00.	0.	0000000000.000000	-0000085.429336546	0.000000000
0.	4.	00.	0.	0000008700.066406	0000007.758300780	0.000026802
0.	4.	01.	0.	0000008700.093750	0000007.940048216	0.000026230
0.	4.	01.	1.	0000008700.074218	0000007.803451538	0.000026660
0.	4.	02.	0.	0000008700.109374	0000011.982482910	0.000005522
0.	4.	02.	1.	0000008700.101562	0000007.986373900	0.000026088
X.	X.	00.	0.	0000000000.000000	-0000085.484527586	0.000000000
0.	4.	00.	0.	0000008800.058592	0000007.808135986	0.000026828
0.	4.	01.	0.	0000008800.082030	0000007.988784790	0.000026066
0.	4.	01.	1.	0000008800.062500	0000007.853012084	0.000026488
0.	4.	02.	0.	0000008800.093750	0000012.014816284	0.000005508
0.	4.	02.	1.	0000008800.089842	0000008.034835814	0.000025928
X.	X.	00.	0.	0000000000.000000	-0000085.539703368	0.000000000
0.	4.	00.	0.	0000008900.050780	0000007.858230590	0.000026452
0.	4.	01.	0.	0000008900.070312	0000008.037765502	0.000025902
0.	4.	01.	1.	0000008900.054686	0000007.902816772	0.000026316
0.	4.	02.	0.	0000008900.085936	0000012.047439574	0.000005492
0.	4.	02.	1.	0000008900.078124	0000008.083541870	0.000025766
X.	X.	00.	0.	0000000000.000000	-0000085.594833374	0.000000000
0.	4.	00.	0.	0000009000.042968	0000007.908554076	0.000026280
0.	4.	01.	0.	0000009000.062500	0000008.087005614	0.000025740
0.	4.	01.	1.	0000009000.046874	0000007.952865600	0.000026146

0.	4.	02.	0.	0000009000.078124	0000012.080337524	0.000005478
0.	4.	02.	1.	0000009000.066406	0000008.132522582	0.000025608
X.	X.	00.	0.	0000000000.000000	-0000085.649902342	0.000000000
0.	4.	00.	0.	0000009100.039062	0000007.959121704	0.000026108
0.	4.	01.	0.	0000009100.054686	0000008.136489868	0.000025580
0.	4.	01.	1.	0000009100.042968	0000008.003173828	0.000025978
0.	4.	02.	0.	0000009100.066406	0000012.113510130	0.000005462
0.	4.	02.	1.	0000009100.058592	0000008.181732176	0.000025450
X.	X.	00.	0.	0000000000.000000	-0000085.704925536	0.000000000
0.	4.	00.	0.	0000009200.031250	0000008.009933470	0.000025938
0.	4.	01.	0.	0000009200.046874	0000008.186218260	0.000025422
0.	4.	01.	1.	0000009200.035156	0000008.053710936	0.000025810
0.	4.	02.	0.	0000009200.058592	0000012.146957396	0.000005446
0.	4.	02.	1.	0000009200.050780	0000008.231201170	0.000025292
X.	X.	00.	0.	0000000000.000000	-0000085.759902954	0.000000000
0.	4.	00.	0.	0000009300.027342	0000008.060958862	0.000025768
0.	4.	01.	0.	0000009300.039062	0000008.236175536	0.000025262
0.	4.	01.	1.	0000009300.031250	0000008.104461668	0.000025642
0.	4.	02.	0.	0000009300.050780	0000012.180679320	0.000005432
0.	4.	02.	1.	0000009300.042968	0000008.280899046	0.000025138
X.	X.	00.	0.	0000000000.000000	-0000085.814788818	0.000000000
0.	4.	00.	0.	0000009400.023436	0000008.112213134	0.000025600
0.	4.	01.	0.	0000009400.035156	0000008.286376952	0.000025106
0.	4.	01.	1.	0000009400.027342	0000008.155456542	0.000025478
0.	4.	02.	0.	0000009400.046874	0000012.214660644	0.000005416
0.	4.	02.	1.	0000009400.039062	0000008.330841064	0.000024982
X.	X.	00.	0.	0000000000.000000	-0000085.869628906	0.000000000
0.	4.	00.	0.	0000009500.019530	0000008.163696288	0.000025434
0.	4.	01.	0.	0000009500.031250	0000008.336807250	0.000024950
0.	4.	01.	1.	0000009500.023436	0000008.206680296	0.000025314
0.	4.	02.	0.	0000009500.039062	0000012.248916624	0.000005400
0.	4.	02.	1.	0000009500.035156	0000008.381011962	0.000024828
X.	X.	00.	0.	0000000000.000000	-0000085.924377440	0.000000000
0.	4.	00.	0.	0000009600.015624	0000008.215393066	0.000025268
0.	4.	01.	0.	0000009600.027342	0000008.387466430	0.000024794
0.	4.	01.	1.	0000009600.019530	0000008.258117674	0.000025152
0.	4.	02.	0.	0000009600.035156	0000012.283447264	0.000005384
0.	4.	02.	1.	0000009600.027342	0000008.431411742	0.000024678
X.	X.	00.	0.	0000000000.000000	-0000085.979064940	0.000000000
0.	4.	00.	0.	0000009700.015624	0000008.267303466	0.000025106
0.	4.	01.	0.	0000009700.023436	0000008.438354492	0.000024640
0.	4.	01.	1.	0000009700.015624	0000008.309768676	0.000024992
0.	4.	02.	0.	0000009700.031250	0000012.318237304	0.000005370
0.	4.	02.	1.	0000009700.023436	0000008.482025146	0.000024526
X.	X.	00.	0.	0000000000.000000	-0000086.033660888	0.000000000
0.	4.	00.	0.	0000009800.011718	0000008.319412230	0.000024942
0.	4.	01.	0.	0000009800.019530	0000008.489440916	0.000024488
0.	4.	01.	1.	0000009800.015624	0000008.361633300	0.000024830
0.	4.	02.	0.	0000009800.027342	0000012.353286742	0.000005354
0.	4.	02.	1.	0000009800.023436	0000008.532867430	0.000024376
X.	X.	00.	0.	0000000000.000000	-0000086.088165282	0.000000000
0.	4.	00.	0.	0000009900.011718	0000008.371734618	0.000024782
0.	4.	01.	0.	0000009900.015624	0000008.540756224	0.000024338
0.	4.	01.	1.	0000009900.011718	0000008.413696288	0.000024672
0.	4.	02.	0.	0000009900.023436	0000012.388595580	0.000005338
0.	4.	02.	1.	0000009900.019530	0000008.583923338	0.000024226
X.	X.	00.	0.	0000000000.000000	-0000086.142578124	0.000000000
0.	4.	00.	0.	0000010000.007812	0000008.424255370	0.000024622
0.	4.	01.	0.	0000010000.015624	0000008.592269896	0.000024186
0.	4.	01.	1.	0000010000.011718	0000008.465957640	0.000024516
0.	4.	02.	0.	0000010000.019530	0000012.424148558	0.000005324
0.	4.	02.	1.	0000010000.015624	0000008.635192870	0.000024078
X.	X.	00.	0.	0000000000.000000	-0000086.196899414	0.000000000

SECTION 2

RAY T	PATH B	TYPE N	TYPE D	HORIZONTAL RANGE (METERS)	TIME DELAY (SECONDS)	GAIN (AMPLITUDE)
Ø.	4.	-Ø1.	Ø.	0000000500.253906	0000000.349411010	Ø.001893212
Ø.	4.	ØØ.	Ø.	0000000500.261718	0000005.171340942	Ø.000040514
Ø.	4.	ØØ.	1.	0000000500.269530	0000000.374481200	Ø.001787336
Ø.	4.	Ø1.	Ø.	0000000500.265624	0000005.438522338	Ø.000038544
Ø.	4.	Ø1.	1.	0000000500.257812	0000005.238342284	Ø.000040004
Ø.	4.	Ø2.	Ø.	0000000500.257812	0000010.494644164	Ø.000006318
Ø.	4.	Ø2.	1.	0000000500.265624	0000005.505554198	Ø.000038080
X.	X.	ØØ.	Ø.	0000000000.000000	-0000051.684600830	Ø.000000000
Ø.	3.	-Ø1.	Ø.	0000001000.250000	0000000.676681518	Ø.000947302
Ø.	4.	ØØ.	Ø.	0000001000.269530	0000005.203430174	Ø.000040262
Ø.	4.	ØØ.	1.	0000001000.347656	0000000.690429686	Ø.000967268
Ø.	4.	Ø1.	Ø.	0000001000.277342	0000005.469146728	Ø.000038326
Ø.	4.	Ø1.	1.	0000001000.273436	0000005.269958496	Ø.000039760
Ø.	4.	Ø2.	Ø.	0000001000.269530	0000010.509948730	Ø.000006308
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Ø.	3.	ØØ.	1.	0000001500.253906	0000001.018417358	Ø.000502262
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Ø.	4.	Ø1.	1.	0000001500.250000	0000005.322311400	Ø.000039364
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Ø.	4.	Ø2.	Ø.	0000002500.246092	0000010.620071410	Ø.000006242
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0.	4.	00.	0.	0000019500.253906	0000013.970977782	0.000014394
0.	4.	01.	0.	0000019500.253906	0000014.075378416	0.000014376
0.	4.	01.	1.	0000019500.253906	0000013.996978758	0.000014392
0.	4.	02.	0.	0000019500.285156	0000016.692398070	0.000003934
0.	4.	02.	1.	0000019500.253906	0000014.102371214	0.000014370

X.	X.	00.	0.	0000000000.000000	-0000090.741500854	0.000000000
0.	4.	00.	0.	0000020000.250000	0000014.280776976	0.000014048
0.	4.	01.	0.	0000020000.253906	0000014.383087158	0.000014040
0.	4.	01.	1.	0000020000.250000	0000014.306259154	0.000014048
0.	4.	02.	0.	0000020000.273436	0000016.952682494	0.000003872
0.	4.	02.	1.	0000020000.253906	0000014.409561156	0.000014036
X.	X.	00.	0.	0000000000.000000	-0000090.947662352	0.000000000
0.	4.	00.	0.	0000020500.250000	0000014.591567992	0.000013716
0.	4.	01.	0.	0000020500.250000	0000014.691894530	0.000013716
0.	4.	01.	1.	0000020500.250000	0000014.616577148	0.000013718
0.	4.	02.	0.	0000020500.265624	0000017.215469360	0.000003812
0.	4.	02.	1.	0000020500.250000	0000014.717864990	0.000013714
X.	X.	00.	0.	0000000000.000000	-0000091.151107788	0.000000000
0.	4.	00.	0.	0000021000.250000	0000014.903289794	0.000013394
0.	4.	01.	0.	0000021000.250000	0000015.001724242	0.000013404
0.	4.	01.	1.	0000021000.250000	0000014.927841186	0.000013400
0.	4.	02.	0.	0000021000.261718	0000017.480636596	0.000003752
0.	4.	02.	1.	0000021000.250000	0000015.027206420	0.000013404
X.	X.	00.	0.	0000000000.000000	-0000091.351928710	0.000000000
0.	4.	00.	0.	0000021500.250000	0000015.215911864	0.000013086
0.	4.	01.	0.	0000021500.250000	0000015.312515258	0.000013102
0.	4.	01.	1.	0000021500.250000	0000015.240005492	0.000013094
0.	4.	02.	0.	0000021500.257812	0000017.748107910	0.000003694
0.	4.	02.	1.	0000021500.250000	0000015.337539672	0.000013104
X.	X.	00.	0.	0000000000.000000	-0000091.550216674	0.000000000
0.	4.	00.	0.	0000022000.250000	0000015.529357910	0.000012786
0.	4.	01.	0.	0000022000.250000	0000015.624206542	0.000012812
0.	4.	01.	1.	0000022000.250000	0000015.553039550	0.000012796
0.	4.	02.	0.	0000022000.253906	0000018.017730712	0.000003636
0.	4.	02.	1.	0000022000.250000	0000015.648788452	0.000012814
X.	X.	00.	0.	0000000000.000000	-0000091.746093750	0.000000000
0.	4.	00.	0.	0000022500.250000	0000015.843582152	0.000012498
0.	4.	01.	0.	0000022500.250000	0000015.936752318	0.000012530
0.	4.	01.	1.	0000022500.250000	0000015.866851806	0.000012510
0.	4.	02.	0.	0000022500.253906	0000018.289474486	0.000003580
0.	4.	02.	1.	0000022500.250000	0000015.960891722	0.000012536
X.	X.	00.	0.	0000000000.000000	-0000091.939636230	0.000000000
0.	4.	00.	0.	0000023000.250000	0000016.158538818	0.000012220
0.	4.	01.	0.	0000023000.250000	0000016.250091552	0.000012258
0.	4.	01.	1.	0000023000.250000	0000016.181411742	0.000012232
0.	4.	02.	0.	0000023000.250000	0000018.563186644	0.000003524
0.	4.	02.	1.	0000023000.250000	0000016.273834228	0.000012266
X.	X.	00.	0.	0000000000.000000	-0000092.130966186	0.000000000
0.	4.	00.	0.	0000023500.246092	0000016.474197386	0.000011950
0.	4.	01.	0.	0000023500.250000	0000016.564193724	0.000011996
0.	4.	01.	1.	0000023500.250000	0000016.496688842	0.000011964
0.	4.	02.	0.	0000023500.250000	0000018.838821410	0.000003472
0.	4.	02.	1.	0000023500.250000	0000016.587524414	0.000012004
X.	X.	00.	0.	0000000000.000000	-0000092.320144652	0.000000000
0.	4.	00.	0.	0000024000.250000	0000016.790496826	0.000011688
0.	4.	01.	0.	0000024000.250000	0000016.878997802	0.000011740
0.	4.	01.	1.	0000024000.250000	0000016.812637328	0.000011706
0.	4.	02.	0.	0000024000.250000	0000019.116256712	0.000003418
0.	4.	02.	1.	0000024000.246092	0000016.901962280	0.000011752
X.	X.	00.	0.	0000000000.000000	-0000092.507293700	0.000000000
0.	4.	00.	0.	0000024500.250000	0000017.107421874	0.000011436
0.	4.	01.	0.	0000024500.250000	0000017.194473266	0.000011494
0.	4.	01.	1.	0000024500.250000	0000017.129196166	0.000011454
0.	4.	02.	0.	0000024500.250000	0000019.395446776	0.000003368
0.	4.	02.	1.	0000024500.250000	0000017.217071532	0.000011506
X.	X.	00.	0.	0000000000.000000	-0000092.692504882	0.000000000
0.	4.	00.	0.	0000025000.250000	0000017.424911498	0.000011192
0.	4.	01.	0.	0000025000.250000	0000017.510589598	0.000011254
0.	4.	01.	1.	0000025000.250000	0000017.446365356	0.000011212
0.	4.	02.	0.	0000025000.250000	0000019.676300048	0.000003318
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X.	X.	00.	0.	0000000000.000000	-0000092.875839232	0.000000000
0.	4.	00.	0.	0000025500.250000	0000017.742950438	0.000010954
0.	4.	01.	0.	0000025500.246092	0000017.827301024	0.000011024
0.	4.	01.	1.	0000025500.246092	0000017.764083862	0.000010976
0.	4.	02.	0.	0000025500.250000	0000019.958755492	0.000003268
0.	4.	02.	1.	0000025500.250000	0000017.849197386	0.000011038
X.	X.	00.	0.	0000000000.000000	-0000093.057418822	0.000000000
0.	4.	00.	0.	0000026000.250000	0000018.061523436	0.000010724
0.	4.	01.	0.	0000026000.250000	0000018.144577026	0.000010798
0.	4.	01.	1.	0000026000.250000	0000018.082336424	0.000010746
0.	4.	02.	0.	0000026000.250000	0000020.242736816	0.000003220
0.	4.	02.	1.	0000026000.250000	0000018.166152954	0.000010814
X.	X.	00.	0.	0000000000.000000	-0000093.237304686	0.000000000
0.	4.	00.	0.	0000026500.250000	0000018.380569458	0.000010500
0.	4.	01.	0.	0000026500.246092	0000018.462387084	0.000010580
0.	4.	01.	1.	0000026500.250000	0000018.401092528	0.000010524
0.	4.	02.	0.	0000026500.250000	0000020.528198242	0.000003174
0.	4.	02.	1.	0000026500.250000	0000018.483657836	0.000010598
X.	X.	00.	0.	0000000000.000000	-0000093.415603636	0.000000000
0.	4.	00.	0.	0000027000.250000	0000018.700088500	0.000010284
0.	4.	01.	0.	0000027000.246092	0000018.780715942	0.000010368
0.	4.	01.	1.	0000027000.250000	0000018.720321654	0.000010308
0.	4.	02.	0.	0000027000.250000	0000020.815063476	0.000003128
0.	4.	02.	1.	0000027000.250000	0000018.801681518	0.000010386
X.	X.	00.	0.	0000000000.000000	-0000093.592376708	0.000000000
0.	4.	00.	0.	0000027500.250000	0000019.020050048	0.000010072
0.	4.	01.	0.	0000027500.250000	0000019.099533080	0.000010162
0.	4.	01.	1.	0000027500.250000	0000019.040008544	0.000010098
0.	4.	02.	0.	0000027500.250000	0000021.103271484	0.000003082
0.	4.	02.	1.	0000027500.246092	0000019.120193480	0.000010182
X.	X.	00.	0.	0000000000.000000	-0000093.767715454	0.000000000
0.	4.	00.	0.	0000028000.351562	0000019.340499876	0.000009868
0.	4.	01.	0.	0000028000.250000	0000019.418792724	0.000009962
0.	4.	01.	1.	0000028000.363280	0000019.360198974	0.000009894
0.	4.	02.	0.	0000028000.250000	0000021.392776488	0.000003038
0.	4.	02.	1.	0000028000.250000	0000019.439193724	0.000009982
X.	X.	00.	0.	0000000000.000000	-0000093.941726684	0.000000000
0.	4.	00.	0.	0000028500.324218	0000019.661254882	0.000009668
0.	4.	01.	0.	0000028500.371092	0000019.738586424	0.000009766
0.	4.	01.	1.	0000028500.335936	0000019.680694580	0.000009696
0.	4.	02.	0.	0000028500.250000	0000021.683532714	0.000002996
0.	4.	02.	1.	0000028500.250000	0000019.758621214	0.000009790
X.	X.	00.	0.	0000000000.000000	-0000094.114425658	0.000000000
0.	4.	00.	0.	0000029000.304686	0000019.982391356	0.000009474
0.	4.	01.	0.	0000029000.343750	0000020.058685302	0.000009576
0.	4.	01.	1.	0000029000.316406	0000020.001586914	0.000009502
0.	4.	02.	0.	0000029000.250000	0000021.975479124	0.000002954
0.	4.	02.	1.	0000029000.355468	0000020.078552246	0.000009600
X.	X.	00.	0.	0000000000.000000	-0000094.285934448	0.000000000
0.	4.	00.	0.	0000029500.292968	0000020.303894042	0.000009284
0.	4.	01.	0.	0000029500.320312	0000020.379180908	0.000009392
0.	4.	01.	1.	0000029500.296874	0000020.322845458	0.000009314
0.	4.	02.	0.	0000029500.246092	0000022.268569946	0.000002914
0.	4.	02.	1.	0000029500.328124	0000020.398788452	0.000009416
X.	X.	00.	0.	0000000000.000000	-0000094.456298828	0.000000000
0.	4.	00.	0.	0000030000.281250	0000020.625732420	0.000009098
0.	4.	01.	0.	0000030000.304686	0000020.700057982	0.000009212
0.	4.	01.	1.	0000030000.285156	0000020.644454956	0.000009130
0.	4.	02.	0.	0000030000.250000	0000022.562759398	0.000002874
0.	4.	02.	1.	0000030000.308592	0000020.719421386	0.000009236
X.	X.	00.	0.	0000000000.000000	-0000094.625610350	0.000000000
0.	4.	00.	0.	0000030500.273436	0000020.947906494	0.000008920
0.	4.	01.	0.	0000030500.289062	0000021.021301268	0.000009036
0.	4.	01.	1.	0000030500.277342	0000020.966400146	0.000008952
0.	4.	02.	0.	0000030500.250000	0000022.858016966	0.000002834
0.	4.	02.	1.	0000030500.296874	0000021.040435790	0.000009062

X.	X.	00.	0.	0000000000.000000	-0000094.793930052	0.000000000
0.	4.	00.	0.	00000031000.265624	0000021.270385742	0.000008744
0.	4.	01.	0.	00000031000.281250	0000021.342880248	0.000008866
0.	4.	01.	1.	00000031000.269530	0000021.288665770	0.000008778
0.	4.	02.	0.	00000031000.250000	0000023.154281616	0.000002794
0.	4.	02.	1.	00000031000.285156	0000021.361785888	0.000008892
X.	X.	00.	0.	0000000000.000000	-0000094.961349486	0.000000000
0.	4.	00.	0.	00000031500.261718	0000021.593170166	0.000008572
0.	4.	01.	0.	00000031500.269530	0000021.664794920	0.000008698
0.	4.	01.	1.	00000031500.265624	0000021.611236572	0.000008608
0.	4.	02.	0.	00000031500.250000	0000023.451538084	0.000002758
0.	4.	02.	1.	00000031500.277342	0000021.683471678	0.000008726
X.	X.	00.	0.	0000000000.000000	-0000095.127914428	0.000000000
0.	4.	00.	0.	00000032000.257812	0000021.916229248	0.000008406
0.	4.	01.	0.	00000032000.265624	0000021.987014770	0.000008534
0.	4.	01.	1.	00000032000.261718	0000021.934097290	0.000008440
0.	4.	02.	0.	00000032000.250000	0000023.749725340	0.000002720
0.	4.	02.	1.	00000032000.269530	0000022.005477904	0.000008564
X.	X.	00.	0.	0000000000.000000	-0000095.293716430	0.000000000
0.	4.	00.	0.	00000032500.253906	0000022.239547728	0.000008242
0.	4.	01.	0.	00000032500.261718	0000022.309524536	0.000008374
0.	4.	01.	1.	00000032500.257812	0000022.257232666	0.000008278
0.	4.	02.	0.	00000032500.250000	0000024.048828124	0.000002684
0.	4.	02.	1.	00000032500.265624	0000022.327789306	0.000008406
X.	X.	00.	0.	0000000000.000000	-0000095.458801268	0.000000000
0.	4.	00.	0.	00000033000.253906	0000022.563140868	0.000008082
0.	4.	01.	0.	00000033000.257812	0000022.632324218	0.000008218
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0.	4.	02.	0.	00000033000.250000	0000024.348815916	0.000002648
0.	4.	02.	1.	00000033000.261718	0000022.650390624	0.000008250
X.	X.	00.	0.	0000000000.000000	-0000095.623245238	0.000000000
0.	4.	00.	0.	00000033500.253906	0000022.886962890	0.000007926
0.	4.	01.	0.	00000033500.253906	0000022.955398558	0.000008066
0.	4.	01.	1.	00000033500.253906	0000022.904281616	0.000007964
0.	4.	02.	0.	00000033500.359374	0000024.649688720	0.000002614
0.	4.	02.	1.	00000033500.257812	0000022.973266600	0.000008098
X.	X.	00.	0.	0000000000.000000	-0000095.787124632	0.000000000
0.	4.	00.	0.	00000034000.250000	0000023.211013792	0.000007772
0.	4.	01.	0.	00000034000.253906	0000023.278732298	0.000007918
0.	4.	01.	1.	00000034000.253906	0000023.228164672	0.000007812
0.	4.	02.	0.	00000034000.335936	0000024.951309204	0.000002580
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X.	X.	00.	0.	0000000000.000000	-0000095.950469970	0.000000000
0.	4.	00.	0.	00000034500.250000	0000023.535308836	0.000007622
0.	4.	01.	0.	00000034500.253906	0000023.602310180	0.000007770
0.	4.	01.	1.	00000034500.250000	0000023.552276610	0.000007662
0.	4.	02.	0.	00000034500.320312	0000025.253707884	0.000002548
0.	4.	02.	1.	00000034500.253906	0000023.619812010	0.000007804
X.	X.	00.	0.	0000000000.000000	-0000096.113388060	0.000000000
0.	4.	00.	0.	00000035000.250000	0000023.859802246	0.000007476
0.	4.	01.	0.	00000035000.250000	0000023.926116942	0.000007628
0.	4.	01.	1.	00000035000.250000	0000023.876617430	0.000007518
0.	4.	02.	0.	00000035000.304686	0000025.556869506	0.000002514
0.	4.	02.	1.	00000035000.253906	0000023.943450926	0.000007662
X.	X.	00.	0.	0000000000.000000	-0000096.275909422	0.000000000
0.	4.	00.	0.	00000035500.250000	0000024.184494018	0.000007334
0.	4.	01.	0.	00000035500.250000	0000024.250152586	0.000007488
0.	4.	01.	1.	00000035500.250000	0000024.201156616	0.000007376
0.	4.	02.	0.	00000035500.292968	0000025.860763548	0.000002482
0.	4.	02.	1.	00000035500.250000	0000024.267318724	0.000007524
0.	4.	03.	0.	00000035500.304686	0000025.973419188	0.000002478
0.	4.	03.	1.	00000035500.296874	0000025.888977050	0.000002480
X.	X.	00.	0.	0000000000.000000	-0000096.208862304	0.000000000
0.	4.	00.	0.	00000036000.250000	0000024.509384154	0.000007192
0.	4.	01.	0.	00000036000.250000	0000024.574417114	0.000007350
0.	4.	01.	1.	00000036000.250000	0000024.525894164	0.000007236

0.	4.	02.	0.	000000360000.285156	00000026.165344238	0.000002452
0.	4.	02.	1.	000000360000.250000	00000024.591415404	0.000007388
0.	4.	03.	0.	000000360000.296874	00000026.276794432	0.000002446
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X.	X.	00.	0.	000000000000.000000	-00000096.368087768	0.000000000
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0.	4.	03.	0.	000000365000.285156	00000026.580856322	0.000002416
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X.	X.	00.	0.	000000000000.000000	-00000096.527038574	0.000000000
0.	4.	00.	0.	000000370000.250000	00000025.159729002	0.000006918
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0.	4.	02.	0.	000000370000.273436	00000026.776535034	0.000002390
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X.	X.	00.	0.	000000000000.000000	-00000096.685806274	0.000000000
0.	4.	00.	0.	000000375000.250000	00000025.485153198	0.000006786
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0.	4.	01.	1.	000000375000.250000	00000025.501235960	0.000006832
0.	4.	02.	0.	000000375000.265624	00000027.083099364	0.000002360
0.	4.	02.	1.	000000375000.250000	00000025.564926146	0.000006994
0.	4.	03.	0.	000000375000.273436	00000027.191024780	0.000002358
0.	4.	03.	1.	000000375000.269530	00000027.110153198	0.000002360
X.	X.	00.	0.	000000000000.000000	-00000096.844421386	0.000000000
0.	4.	00.	0.	000000380000.250000	00000025.810745238	0.000006656
0.	4.	01.	0.	000000380000.250000	00000025.873413084	0.000006828
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0.	4.	02.	0.	000000380000.265624	00000027.390258788	0.000002332
0.	4.	02.	1.	000000380000.250000	00000025.889816284	0.000006868
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X.	X.	00.	0.	000000000000.000000	-00000097.002944946	0.000000000
0.	4.	00.	0.	000000385000.250000	00000026.136489868	0.000006528
0.	4.	01.	0.	000000385000.250000	00000026.198623656	0.000006704
0.	4.	01.	1.	000000385000.250000	00000026.152313232	0.000006576
0.	4.	02.	0.	000000385000.257812	00000027.698013304	0.000002304
0.	4.	02.	1.	000000385000.250000	00000026.214889526	0.000006744
0.	4.	03.	0.	000000385000.261718	00000027.803741454	0.000002302
0.	4.	03.	1.	000000385000.261718	00000027.724533080	0.000002304
X.	X.	00.	0.	000000000000.000000	-00000097.161437988	0.000000000
0.	4.	00.	0.	000000390000.250000	00000026.462387084	0.000006402
0.	4.	01.	0.	000000390000.250000	00000026.524002074	0.000006580
0.	4.	01.	1.	000000390000.250000	00000026.478088378	0.000006450
0.	4.	02.	0.	000000390000.257812	00000028.006347656	0.000002276
0.	4.	02.	1.	000000390000.250000	00000026.540130614	0.000006622
0.	4.	03.	0.	000000390000.261718	00000028.110992430	0.000002274
0.	4.	03.	1.	000000390000.257812	00000028.032592772	0.000002276
X.	X.	00.	0.	000000000000.000000	-00000097.319961546	0.000000000
0.	4.	00.	0.	000000395000.250000	00000026.788436888	0.000006278
0.	4.	01.	0.	000000395000.250000	00000026.849533080	0.000006460
0.	4.	01.	1.	000000395000.250000	00000026.804016112	0.000006328
0.	4.	02.	0.	000000395000.257812	00000028.315231322	0.000002248
0.	4.	02.	1.	000000395000.246092	00000026.865524290	0.000006502
0.	4.	03.	0.	000000395000.257812	00000028.418823242	0.000002248
0.	4.	03.	1.	000000395000.257812	00000028.341217040	0.000002248
X.	X.	00.	0.	000000000000.000000	-00000097.478576660	0.000000000
0.	4.	00.	0.	000000400000.250000	00000027.114608764	0.000006158
0.	4.	01.	0.	000000400000.250000	00000027.175231932	0.000006342
0.	4.	01.	1.	000000400000.250000	00000027.130081176	0.000006206
0.	4.	02.	0.	000000400000.253906	00000028.624649046	0.000002222
0.	4.	02.	1.	000000400000.250000	00000027.191101074	0.000006384

0.	4.	03.	0.	0000040000.253906	0000028.727218626	0.000002220
0.	4.	03.	1.	0000040000.253906	0000028.650375366	0.000002222
X.	X.	00.	0.	0000000000.000000	-0000097.637329100	0.000000000
0.	4.	00.	0.	0000040500.250000	0000027.440933226	0.000006038
0.	4.	01.	0.	0000040500.250000	0000027.501068114	0.000006226
0.	4.	01.	1.	0000040500.250000	0000027.456283568	0.000006088
0.	4.	02.	0.	0000040500.253906	0000028.934570312	0.000002196
0.	4.	02.	1.	0000040500.250000	0000027.516815184	0.000006268
0.	4.	03.	0.	0000040500.253906	0000029.036132812	0.000002194
0.	4.	03.	1.	0000040500.253906	0000028.960067748	0.000002196
X.	X.	00.	0.	0000000000.000000	-0000097.796279906	0.000000000
0.	4.	00.	0.	0000041000.246092	0000027.767364500	0.000005920
0.	4.	01.	0.	0000041000.250000	0000027.827041624	0.000006112
0.	4.	01.	1.	0000041000.250000	0000027.782608032	0.000005970
0.	4.	02.	0.	0000041000.250000	0000029.244995116	0.000002168
0.	4.	02.	1.	0000041000.250000	0000027.842681884	0.000006154
0.	4.	03.	0.	0000041000.253906	0000029.345581054	0.000002168
0.	4.	03.	1.	0000041000.253906	0000029.270248412	0.000002168
X.	X.	00.	0.	0000000000.000000	-0000097.955490112	0.000000000
0.	4.	00.	0.	0000041500.250000	0000028.003917846	0.000005804
0.	4.	01.	0.	0000041500.246092	0000028.153152464	0.000005998
0.	4.	01.	1.	0000041500.250000	0000028.109069824	0.000005856
0.	4.	02.	0.	0000041500.250000	0000029.555908202	0.000002144
0.	4.	02.	1.	0000041500.250000	0000028.168670654	0.000006042
0.	4.	03.	0.	0000041500.250000	0000029.655532836	0.000002144
0.	4.	03.	1.	0000041500.250000	0000029.580932616	0.000002144
X.	X.	00.	0.	0000000000.000000	-0000098.115020750	0.000000000
0.	4.	00.	0.	0000042000.250000	0000028.420593260	0.000005692
0.	4.	01.	0.	0000042000.250000	0000028.479400634	0.000005888
0.	4.	01.	1.	0000042000.250000	0000028.435638426	0.000005742
0.	4.	02.	0.	0000042000.250000	0000029.867294310	0.000002118
0.	4.	02.	1.	0000042000.250000	0000028.494812010	0.000005932
0.	4.	03.	0.	0000042000.250000	0000029.965957640	0.000002120
0.	4.	03.	1.	0000042000.250000	0000029.892074584	0.000002118
X.	X.	00.	0.	0000000000.000000	-0000098.274917602	0.000000000
0.	4.	00.	0.	0000042500.250000	0000028.747390746	0.000005580
0.	4.	01.	0.	0000042500.250000	0000028.805770874	0.000005778
0.	4.	01.	1.	0000042500.250000	0000028.762329100	0.000005630
0.	4.	02.	0.	0000042500.250000	0000030.179138182	0.000002094
0.	4.	02.	1.	0000042500.250000	0000028.821075438	0.000005824
0.	4.	03.	0.	0000042500.250000	0000030.276870726	0.000002096
0.	4.	03.	1.	0000042500.250000	0000030.203689574	0.000002094
X.	X.	00.	0.	0000000000.000000	-0000098.435256958	0.000000000
0.	4.	00.	0.	0000043000.250000	0000029.074279784	0.000005468
0.	4.	01.	0.	0000043000.250000	0000029.132263182	0.000005670
0.	4.	01.	1.	0000043000.250000	0000029.089141844	0.000005520
0.	4.	02.	0.	0000043000.250000	0000030.491409300	0.000002070
0.	4.	02.	1.	0000043000.250000	0000029.147476196	0.000005716
0.	4.	03.	0.	0000043000.250000	0000030.588241576	0.000002072
0.	4.	03.	1.	0000043000.250000	0000030.515731810	0.000002070
X.	X.	00.	0.	0000000000.000000	-0000098.596084594	0.000000000
0.	4.	00.	0.	0000043500.250000	0000029.401275634	0.000005360
0.	4.	01.	0.	0000043500.250000	0000029.458877562	0.000005564
0.	4.	01.	1.	0000043500.250000	0000029.416046142	0.000005412
0.	4.	02.	0.	0000043500.250000	0000030.804107666	0.000002046
0.	4.	02.	1.	0000043500.246092	0000029.473983764	0.000005612
0.	4.	03.	0.	0000043500.250000	0000030.900054930	0.000002048
0.	4.	03.	1.	0000043500.250000	0000030.828216552	0.000002046
X.	X.	00.	0.	0000000000.000000	-0000098.757461546	0.000000000
0.	4.	00.	0.	0000044000.250000	0000029.728378294	0.000005252
0.	4.	01.	0.	0000044000.250000	0000029.785598754	0.000005460
0.	4.	01.	1.	0000044000.246092	0000029.743057250	0.000005306
0.	4.	02.	0.	0000044000.250000	0000031.117218016	0.000002024
0.	4.	02.	1.	0000044000.250000	0000029.800613402	0.000005506
0.	4.	03.	0.	0000044000.250000	0000031.212295532	0.000002026
0.	4.	03.	1.	0000044000.250000	0000031.141128540	0.000002024

X.	X.	00.	0.	0000000000.000000	-0000098.919464110	0.000000000
0.	4.	00.	0.	0000044500.250000	0000030.055557250	0.000005146
0.	4.	01.	0.	0000044500.250000	0000030.112426756	0.000005356
0.	4.	01.	1.	0000044500.250000	0000030.070159912	0.000005202
0.	4.	02.	0.	0000044500.250000	0000031.430740356	0.000002000
0.	4.	02.	1.	0000044500.250000	0000030.127334594	0.000005404
0.	4.	03.	0.	0000044500.250000	0000031.524963378	0.000002002
0.	4.	03.	1.	0000044500.250000	0000031.454421996	0.000002002
X.	X.	00.	0.	0000000000.000000	-0000099.082153320	0.000000000
0.	4.	00.	0.	0000045000.250000	0000030.382843016	0.000005042
0.	4.	01.	0.	0000045000.250000	0000030.439361572	0.000005256
0.	4.	01.	1.	0000045000.250000	0000030.397354124	0.000005098
0.	4.	02.	0.	0000045000.250000	0000031.744644164	0.000001978
0.	4.	02.	1.	0000045000.250000	0000030.454177856	0.000005304
0.	4.	03.	0.	0000045000.250000	0000031.838027954	0.000001980
0.	4.	03.	1.	0000045000.250000	0000031.768127440	0.000001978
X.	X.	00.	0.	0000000000.000000	-0000099.245574950	0.000000000
0.	4.	00.	0.	0000045500.250000	0000030.710205078	0.000004940
0.	4.	01.	0.	0000045500.250000	0000030.766387938	0.000005154
0.	4.	01.	1.	0000045500.250000	0000030.724639892	0.000004994
0.	4.	02.	0.	0000045500.250000	0000032.058914184	0.000001956
0.	4.	02.	1.	0000045500.250000	0000030.781127928	0.000005204
0.	4.	03.	0.	0000045500.250000	0000032.151489256	0.000001958
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X.	X.	00.	0.	0000000000.000000	-0000099.409820556	0.000000000
0.	4.	00.	0.	0000046000.250000	0000031.037658690	0.000004838
0.	4.	01.	0.	0000046000.250000	0000031.093505858	0.000005056
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0.	4.	02.	0.	0000046000.250000	0000032.373565672	0.000001934
0.	4.	02.	1.	0000046000.250000	0000031.108169554	0.000005106
0.	4.	03.	0.	0000046000.250000	0000032.465332030	0.000001938
0.	4.	03.	1.	0000046000.250000	0000032.396652220	0.000001936
X.	X.	00.	0.	0000000000.000000	-0000099.574951170	0.000000000
0.	3.	00.	0.	0000046500.253906	0000031.229660034	0.000039986
0.	4.	00.	0.	0000046500.359374	0000031.365264892	0.000004738
0.	4.	01.	0.	0000046500.250000	0000031.420730590	0.000004958
0.	4.	01.	1.	0000046500.250000	0000031.379486082	0.000004794
0.	4.	02.	0.	0000046500.250000	0000032.688568114	0.000001912
0.	4.	02.	1.	0000046500.250000	0000031.435302734	0.000005008
0.	4.	03.	0.	0000046500.250000	0000032.779541014	0.000001916
0.	4.	03.	1.	0000046500.250000	0000032.711456298	0.000001914
X.	X.	00.	0.	0000000000.000000	-0000087.682662962	0.000000000
0.	3.	00.	0.	0000047000.250000	0000031.563858032	0.000022506
0.	4.	00.	0.	0000047000.339842	0000031.692855834	0.000004638
0.	4.	01.	0.	0000047000.250000	0000031.748031616	0.000004860
0.	4.	01.	1.	0000047000.355468	0000031.707077026	0.000004696
0.	4.	02.	0.	0000047000.250000	0000033.003906250	0.000001892
0.	4.	02.	1.	0000047000.250000	0000031.762527464	0.000004912
0.	4.	03.	0.	0000047000.250000	0000033.094116210	0.000001896
0.	4.	03.	1.	0000047000.250000	0000033.026626586	0.000001894
X.	X.	00.	0.	0000000000.000000	-0000092.155822752	0.000000000
0.	4.	00.	0.	0000047500.324218	0000032.020523070	0.000004542
0.	4.	01.	0.	0000047500.250000	0000032.075424194	0.000004766
0.	4.	01.	1.	0000047500.332030	0000032.034683226	0.000004598
0.	4.	02.	0.	0000047500.250000	0000033.319595336	0.000001870
0.	4.	02.	1.	0000047500.250000	0000032.089828490	0.000004816
0.	4.	03.	0.	0000047500.250000	0000033.409042358	0.000001874
0.	4.	03.	1.	0000047500.250000	0000033.342117308	0.000001872
X.	X.	00.	0.	0000000000.000000	-0000100.076339720	0.000000000
0.	3.	01.	1.	0000048000.351562	0000032.237564086	0.000030654
0.	4.	00.	0.	0000048000.308592	0000032.348266600	0.000004444
0.	4.	01.	0.	0000048000.359374	0000032.402954100	0.000004672
0.	4.	01.	1.	0000048000.320312	0000032.362365722	0.000004502
0.	4.	02.	0.	0000048000.250000	0000033.635604858	0.000001852
0.	4.	02.	1.	0000048000.371092	0000032.417312622	0.000004722
0.	4.	03.	0.	0000048000.250000	0000033.724304198	0.000001856

0.	4.	03.	1.	0000048000.250000	0000033.657943724	0.000001852
X.	X.	00.	0.	0000000000.000000	-0000089.853897094	0.000000000
0.	3.	00.	0.	0000048500.359374	0000032.564437866	0.000029160
0.	3.	01.	1.	0000048500.273436	0000032.571731566	0.000016108
0.	4.	00.	0.	0000048500.296874	0000032.676086424	0.000004348
0.	4.	01.	0.	0000048500.339842	0000032.730499266	0.000004578
0.	4.	01.	1.	0000048500.308592	0000032.690109252	0.000004406
0.	4.	02.	0.	0000048500.250000	0000033.951919554	0.000001830
0.	4.	02.	1.	0000048500.351562	0000032.744766234	0.000004630
0.	4.	03.	0.	0000048500.246092	0000034.039901732	0.000001836
0.	4.	03.	1.	0000048500.250000	0000033.974075316	0.000001832
X.	X.	00.	0.	0000000000.000000	-0000089.205490112	0.000000000
0.	3.	00.	0.	0000049000.250000	0000032.897766112	0.000027758
0.	4.	00.	0.	0000049000.285156	0000033.003967284	0.000004254
0.	4.	01.	0.	0000049000.324218	0000033.058105468	0.000004486
0.	4.	01.	1.	0000049000.296874	0000033.017929076	0.000004312
0.	4.	02.	0.	0000049000.250000	0000034.268554686	0.000001812
0.	4.	02.	1.	0000049000.335936	0000033.072311400	0.000004538
0.	4.	03.	0.	0000049000.250000	0000034.355804442	0.000001816
0.	4.	03.	1.	0000049000.250000	0000034.290542602	0.000001812
X.	X.	00.	0.	0000000000.000000	-0000090.665588378	0.000000000
0.	3.	00.	0.	0000049500.246092	0000033.231063842	0.000026570
0.	3.	01.	1.	0000049500.328124	0000033.238204956	0.000029322
0.	4.	00.	0.	0000049500.281250	0000033.331909178	0.000004160
0.	4.	01.	0.	0000049500.312500	0000033.385787962	0.000004394
0.	4.	01.	1.	0000049500.289062	0000033.345809936	0.000004218
0.	4.	02.	0.	0000049500.250000	0000034.585479736	0.000001792
0.	4.	02.	1.	0000049500.320312	0000033.399932860	0.000004448
0.	4.	03.	0.	0000049500.250000	0000034.672027586	0.000001796
0.	4.	03.	1.	0000049500.250000	0000034.607299804	0.000001794
X.	X.	00.	0.	0000000000.000000	-0000087.825698852	0.000000000
0.	3.	00.	0.	0000050000.246092	0000033.564254760	0.000025538
0.	3.	01.	1.	0000050000.250000	0000033.571548460	0.000027812
0.	4.	00.	0.	0000050000.277342	0000033.659912108	0.000004068
0.	4.	01.	0.	0000050000.296874	0000033.713531494	0.000004304
0.	4.	01.	1.	0000050000.277342	0000033.673751830	0.000004128
0.	4.	02.	0.	0000050000.246092	0000034.902694702	0.000001774
0.	4.	02.	1.	0000050000.304686	0000033.727615356	0.000004358
0.	4.	03.	0.	0000050000.250000	0000034.988555908	0.000001778
0.	4.	03.	1.	0000050000.250000	0000034.924346922	0.000001774
X.	X.	00.	0.	0000000000.000000	-0000088.220947264	0.000000000
0.	3.	00.	0.	0000050500.359374	0000033.897430418	0.000024624
0.	3.	01.	1.	0000050500.250000	0000033.904830932	0.000026550
0.	4.	00.	0.	0000050500.273436	0000033.987960814	0.000003976
0.	4.	01.	0.	0000050500.289062	0000034.041351318	0.000004214
0.	4.	01.	1.	0000050500.273436	0000034.001754760	0.000004036
0.	4.	02.	0.	0000050500.246092	0000035.220184326	0.000001754
0.	4.	02.	1.	0000050500.296874	0000034.055374144	0.000004270
0.	4.	03.	0.	0000050500.250000	0000035.305389404	0.000001760
0.	4.	03.	1.	0000050500.250000	0000035.241668700	0.000001756
X.	X.	00.	0.	0000000000.000000	-0000088.573898314	0.000000000
0.	3.	00.	0.	0000051000.269530	0000034.230361938	0.000023804
0.	3.	01.	1.	0000051000.246092	0000034.238006590	0.000025468
0.	4.	00.	0.	0000051000.269530	0000034.316070556	0.000003886
0.	4.	01.	0.	0000051000.281250	0000034.369247436	0.000004126
0.	4.	01.	1.	0000051000.273436	0000034.329818724	0.000003946
0.	4.	02.	0.	0000051000.250000	0000035.537963866	0.000001736
0.	4.	02.	1.	0000051000.289062	0000034.383193968	0.000004180
0.	4.	03.	0.	0000051000.246092	0000035.622497558	0.000001740
0.	4.	03.	1.	0000051000.246092	0000035.559280394	0.000001736
X.	X.	00.	0.	0000000000.000000	-0000088.895309448	0.000000000
0.	3.	00.	0.	0000051500.253906	0000034.563232420	0.000023062
0.	3.	01.	1.	0000051500.359374	0000034.571151732	0.000024520
0.	4.	00.	0.	0000051500.261718	0000034.644241332	0.000003796
0.	4.	01.	0.	0000051500.281250	0000034.697189330	0.000004038
0.	4.	01.	1.	0000051500.265624	0000034.657928466	0.000003856

0.	4.	02.	0.	0000051500.246092	0000035.856002806	0.000001718
0.	4.	02.	1.	0000051500.281250	0000034.711090086	0.000004094
0.	4.	03.	0.	0000051500.250000	0000035.939880370	0.000001722
0.	4.	03.	1.	0000051500.250000	0000035.877166748	0.000001720
X.	X.	00.	0.	0000000000.000000	-0000089.192230224	0.000000000
0.	3.	00.	0.	0000052000.246092	0000034.896026610	0.000022384
0.	3.	01.	1.	0000052000.277342	0000034.904067992	0.000023676
0.	4.	00.	0.	0000052000.261718	0000034.972457884	0.000003706
0.	4.	01.	0.	0000052000.269530	0000035.025192260	0.000003950
0.	4.	01.	1.	0000052000.265624	0000034.986099242	0.000003768
0.	4.	02.	0.	0000052000.250000	0000036.174301146	0.000001700
0.	4.	02.	1.	0000052000.273436	0000035.039031982	0.000004006
0.	4.	03.	0.	0000052000.250000	0000036.257553100	0.000001706
0.	4.	03.	1.	0000052000.250000	0000036.195312500	0.000001702
X.	X.	00.	0.	0000000000.000000	-0000089.469345092	0.000000000
0.	3.	00.	0.	0000052500.246092	0000035.228713988	0.000021760
0.	3.	01.	1.	0000052500.253906	0000035.236907958	0.000022914
0.	4.	00.	0.	0000052500.257812	0000035.300720214	0.000003618
0.	4.	01.	0.	0000052500.269530	0000035.353256224	0.000003864
0.	4.	01.	1.	0000052500.261718	0000035.314315794	0.000003680
0.	4.	02.	0.	0000052500.250000	0000036.492858886	0.000001682
0.	4.	02.	1.	0000052500.269530	0000035.367050170	0.000003920
0.	4.	03.	0.	0000052500.250000	0000036.575469970	0.000001688
0.	4.	03.	1.	0000052500.250000	0000036.513717650	0.000001684
X.	X.	00.	0.	0000000000.000000	-0000089.730117796	0.000000000
0.	3.	00.	0.	0000053000.246092	0000035.561309814	0.000021180
0.	3.	01.	0.	0000053000.250000	0000035.588287352	0.000035768
0.	3.	01.	0.	0000053000.347656	0000035.588470458	0.000038624
0.	3.	01.	1.	0000053000.250000	0000035.569656372	0.000022222
0.	4.	00.	0.	0000053000.261718	0000035.629043578	0.000003530
0.	4.	01.	0.	0000053000.265624	0000035.681365966	0.000003780
0.	4.	01.	1.	0000053000.261718	0000035.642593382	0.000003592
0.	4.	02.	0.	0000053000.250000	0000036.811645506	0.000001664
0.	4.	02.	1.	0000053000.269530	0000035.695114134	0.000003836
0.	4.	03.	0.	0000053000.250000	0000036.893661498	0.000001670
0.	4.	03.	1.	0000053000.250000	0000036.832366942	0.000001666
X.	X.	00.	0.	0000000000.000000	-0000084.228988646	0.000000000
0.	3.	00.	0.	0000053500.246092	0000035.893798828	0.000020642
0.	3.	01.	0.	0000053500.250000	0000035.921752928	0.000030568
0.	3.	01.	0.	0000053500.250000	0000035.922409056	0.000032370
0.	3.	01.	1.	0000053500.246092	0000035.902313232	0.000021588
0.	4.	00.	0.	0000053500.257812	0000035.957382202	0.000003444
0.	4.	01.	0.	0000053500.265624	0000036.009536742	0.000003694
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0.	4.	02.	0.	0000053500.246092	0000037.130691528	0.000001648
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0.	4.	03.	1.	0000053500.250000	0000037.151245116	0.000001650
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0.	3.	01.	0.	0000054000.304686	0000036.256515502	0.000028382
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0.	4.	03.	1.	0000054000.250000	0000037.470382690	0.000001632
X.	X.	00.	0.	0000000000.000000	-0000082.662170410	0.000000000
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0.	3.	01.	0.	0000054500.250000	0000036.588165282	0.000026140
0.	3.	01.	0.	0000054500.253906	0000036.590606688	0.000025208

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0.	4.	01.	1.	00000545000.253906	0000036.627655028	0.00000003334
0.	4.	02.	0.	00000545000.250000	0000037.769454956	0.00000001614
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X.	X.	00.	0.	00000000000.000000	-0000083.758010864	0.00000000000
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0.	3.	01.	0.	00000055000.355468	0000036.921234130	0.00000024756
0.	3.	01.	0.	00000055000.250000	0000036.924743652	0.00000022460
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0.	4.	02.	0.	00000055000.250000	0000038.089172362	0.00000001598
0.	4.	02.	1.	00000055000.257812	0000037.007873534	0.00000003502
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0.	3.	01.	1.	00000055500.246092	0000037.231887816	0.00000019476
0.	3.	02.	1.	00000055500.347656	0000037.261962890	0.00000025962
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X.	X.	00.	0.	00000000000.000000	-0000085.102340698	0.00000000000
0.	3.	00.	0.	00000056000.246092	0000037.554748534	0.00000018402
0.	3.	01.	0.	00000056000.261718	0000037.586761474	0.00000022678
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0.	3.	02.	1.	00000056000.292968	0000037.594879150	0.00000024552
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0.	4.	01.	0.	00000056000.257812	0000037.651077270	0.00000003280
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0.	3.	00.	0.	00000056500.246092	0000037.886627196	0.00000018024
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0.	3.	01.	0.	00000056500.304686	0000037.927352904	0.00000015376
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X.	X.	00.	0.	0000000000.000000	-0000086.173263548	0.000000000
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0.	4.	02.	0.	0000059500.335936	0000040.975769042	0.000001458
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0.	3.	02.	1.	0000060000.246092	0000040.253875732	0.000018614
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0.	4.	00.	0.	0000060000.253906	0000040.229110716	0.000002350
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0.	4.	03.	0.	0000060000.347656	0000041.371887206	0.000001452
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0.	4.	01.	0.	0000060500.253906	0000040.608154296	0.000002556
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0.	3.	02.	1.	0000061000.246092	0000040.917434692	0.000017726
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0.	4.	04.	0.	0000091500.339842	0000062.934616088	0.000000298
0.	4.	04.	1.	0000091500.250000	0000061.853393554	0.000000804
X.	X.	00.	0.	0000000000.000000	-0000115.817459106	0.000000000
0.	4.	02.	0.	0000092000.250000	0000062.110076904	0.000000776
0.	4.	03.	0.	0000092000.250000	0000062.165985106	0.000000792
0.	4.	03.	1.	0000092000.253906	0000062.124496458	0.000000780
0.	4.	04.	0.	0000092000.332030	0000063.256622314	0.000000296
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0.	4.	03.	0.	0000092500.253906	0000062.493255614	0.000000786
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0.	4.	04.	0.	0000092500.324218	0000063.578735350	0.000000294
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0.	4.	03.	0.	0000093000.250000	0000062.820541380	0.000000776
0.	4.	03.	1.	0000093000.246092	0000062.779296874	0.000000764
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X.	X.	00.	0.	0000000000.000000	-0000116.335662840	0.000000000
0.	4.	02.	0.	0000095000.250000	0000064.075164794	0.000000728
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0.	4.	02.	0.	0000095500.250000	0000064.402816772	0.000000720
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0.	4.	04.	1.	0000095500.246092	0000064.471984862	0.000000744
X.	X.	00.	0.	0000000000.000000	-0000116.511093138	0.000000000
0.	4.	02.	0.	0000096000.253906	0000064.730499266	0.000000714
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0.	4.	04.	1.	0000099500.359374	0000067.093154906	0.0000006840
X.	X.	00.	0.	0000000000.000000	-0000092.562896728	0.0000000000
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0.	3.	03.	1.	0000100000.257812	0000067.152648924	0.0000012782
0.	4.	02.	0.	0000100000.316406	0000067.353240966	0.0000006540
0.	4.	03.	0.	0000100000.339842	0000067.406921386	0.0000006740
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0.	4.	04.	0.	0000100000.265624	0000068.422119140	0.0000002680
0.	4.	04.	1.	0000100000.347656	0000067.420944212	0.0000006780
X.	X.	00.	0.	0000000000.000000	-0000091.493591308	0.0000000000

SECTION 3

```
 00.  TOP  BOTTOM  CYCLES  VECTOR
       0.     3.    -01.     0.

    PREVIOUS Z        PREVIOUS DERIVATIVE    SIN(ANGLE)
0000001498.593750  -0000000284.908126830   0.996600862

  PREVIOUS RANGE         TIME DELAY           GAIN
0000002099.996092   0000001.408538818    0.000394674


 00.  TOP  BOTTOM  CYCLES  VECTOR
       0.     3.     00.     1.

    PREVIOUS Z        PREVIOUS DERIVATIVE    SIN(ANGLE)
0000001504.148436  -0000000101.844329832   0.992916944

  PREVIOUS RANGE         TIME DELAY           GAIN
0000002100.039062   0000001.416076660    0.000412424


 00.  TOP  BOTTOM  CYCLES  VECTOR
       0.     4.     00.     0.

    PREVIOUS Z        PREVIOUS DERIVATIVE    SIN(ANGLE)
0000005742.210936  -0000000000.392578124   0.260091148

  PREVIOUS RANGE         TIME DELAY           GAIN
0000002100.031250   0000005.346755980    0.000039170


 00.  TOP  BOTTOM  CYCLES  VECTOR
       0.     4.     01.     0.

    PREVIOUS Z        PREVIOUS DERIVATIVE    SIN(ANGLE)
0000006017.187500  -0000000000.372192382   0.248205460

  PREVIOUS RANGE         TIME DELAY           GAIN
0000002100.039062   0000005.605712890    0.000037382


 00.  TOP  BOTTOM  CYCLES  VECTOR
       0.     4.     01.     1.

    PREVIOUS Z        PREVIOUS DERIVATIVE    SIN(ANGLE)
0000005810.757812  -0000000000.387283324   0.257023218

  PREVIOUS RANGE         TIME DELAY           GAIN
0000002100.031250   0000005.411529540    0.000038708
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```
 ØØ.  TOP  BOTTOM  CYCLES  VECTOR
       Ø.     4.     Ø2.     Ø.

    PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000011362.117186  -0000000000.188125610   Ø.131445524

   PREVIOUS RANGE          TIME DELAY          GAIN
0000002100.023436   0000010.581558226   Ø.000006264


 ØØ.  TOP  BOTTOM  CYCLES  VECTOR
       Ø.     4.     Ø2.     1.

    PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000006085.953124  -0000000000.367431640   Ø.245400968

   PREVIOUS RANGE          TIME DELAY          GAIN
0000002100.042968   0000005.670700072   Ø.000036960


 ØØ.  TOP  BOTTOM  CYCLES  VECTOR
       X.     X.     ØØ.     Ø.

    PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000000000.000000   0000000000.000000000   Ø.000000000

   PREVIOUS RANGE          TIME DELAY          GAIN
0000000000.000000  -0000064.792724608   Ø.000000000


 ØØ.  TOP  BOTTOM  CYCLES  VECTOR
       Ø.     3.    -Ø1.     Ø.

    PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000001498.265624  -0000000329.641052246   Ø.996818006

   PREVIOUS RANGE          TIME DELAY          GAIN
0000002200.000000   0000001.475265502   Ø.000370048


 ØØ.  TOP  BOTTOM  CYCLES  VECTOR
       Ø.     3.     ØØ.     1.

    PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000001503.234374  -0000000117.455734252   Ø.993520966

   PREVIOUS RANGE          TIME DELAY          GAIN
0000002200.019530   0000001.482559204   Ø.000397474


 ØØ.  TOP  BOTTOM  CYCLES  VECTOR
       Ø.     4.     ØØ.     Ø.

    PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000005499.484374  -0000000000.432296752   Ø.271570660

   PREVIOUS RANGE          TIME DELAY          GAIN
0000002200.019530   0000005.364547728   Ø.000039038
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00.  TOP  BOTTOM  CYCLES  VECTOR
      0.     4.     01.     0.

   PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000005761.132812  -0000000000.409713744   0.259237012

  PREVIOUS RANGE          TIME DELAY           GAIN
0000002200.023436   0000005.622711180   0.000037266


00.  TOP  BOTTOM  CYCLES  VECTOR
      0.     4.     01.     1.

   PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000005564.695312  -0000000000.426422118   0.268388286

  PREVIOUS RANGE          TIME DELAY           GAIN
0000002200.019530   0000005.429122924   0.000038580


00.  TOP  BOTTOM  CYCLES  VECTOR
      0.     4.     02.     0.

   PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000010854.953124  -0000000000.206634520   0.137586862

  PREVIOUS RANGE          TIME DELAY           GAIN
0000002200.015624   0000010.590499876   0.000006258


00.  TOP  BOTTOM  CYCLES  VECTOR
      0.     4.     02.     1.

   PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000005826.578124  -0000000000.404449462   0.256325278

  PREVIOUS RANGE          TIME DELAY           GAIN
0000002200.027342   0000005.687500000   0.000036848


00.  TOP  BOTTOM  CYCLES  VECTOR
      X.     X.     00.     0.

   PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000000000.000000   0000000000.000000000   0.000000000

  PREVIOUS RANGE          TIME DELAY           GAIN
0000000000.000000  -0000065.218505858   0.000000000


00.  TOP  BOTTOM  CYCLES  VECTOR
      0.     3.    -01.     0.

   PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000001497.984374  -0000000379.424057006   0.997006242

  PREVIOUS RANGE          TIME DELAY           GAIN
0000002300.000000   0000001.542022704   0.000347344
```

```
 ØØ.  TOP  BOTTOM  CYCLES  VECTOR
       Ø.     3.     ØØ.     1.

    PREVIOUS Z        PREVIOUS DERIVATIVE    SIN(ANGLE)
ØØØØØØ1502.437500  -ØØØØØØØ134.781660156   Ø.994046810

   PREVIOUS RANGE         TIME DELAY          GAIN
ØØØØØØ2300.ØØ7812   ØØØØØØ1.549102782   Ø.ØØØ382890


 ØØ.  TOP  BOTTOM  CYCLES  VECTOR
       Ø.     4.     ØØ.     Ø.

    PREVIOUS Z        PREVIOUS DERIVATIVE    SIN(ANGLE)
ØØØØØØ5278.ØØ1562  -ØØØØØØØØØØ.474121092   Ø.282934486

   PREVIOUS RANGE         TIME DELAY          GAIN
ØØØØØØ2300.ØØ1718   ØØØØØØ5.383117674   Ø.ØØØØ38902


 ØØ.  TOP  BOTTOM  CYCLES  VECTOR
       Ø.     4.     Ø1.     Ø.

    PREVIOUS Z        PREVIOUS DERIVATIVE    SIN(ANGLE)
ØØØØØØ5528.Ø46874  -ØØØØØØØØØØ.449218750   Ø.270167510

   PREVIOUS RANGE         TIME DELAY          GAIN
ØØØØØØ2300.Ø15624   ØØØØØØ5.640426634   Ø.ØØØØ37148


 ØØ.  TOP  BOTTOM  CYCLES  VECTOR
       Ø.     4.     Ø1.     1.

    PREVIOUS Z        PREVIOUS DERIVATIVE    SIN(ANGLE)
ØØØØØØ5340.765624  -ØØØØØØØØØØ.467636108   Ø.279641342

   PREVIOUS RANGE         TIME DELAY          GAIN
ØØØØØØ2300.ØØ7812   ØØØØØØ5.447448730   Ø.ØØØØ38450


 ØØ.  TOP  BOTTOM  CYCLES  VECTOR
       Ø.     4.     Ø2.     Ø.

    PREVIOUS Z        PREVIOUS DERIVATIVE    SIN(ANGLE)
ØØØØØ10392.257812  -ØØØØØØØØØØ.226043700   Ø.143712740

   PREVIOUS RANGE         TIME DELAY          GAIN
ØØØØØØ2300.ØØ7812   ØØØØØ10.599975584   Ø.ØØØØØ6252


 ØØ.  TOP  BOTTOM  CYCLES  VECTOR
       Ø.     4.     Ø2.     1.

    PREVIOUS Z        PREVIOUS DERIVATIVE    SIN(ANGLE)
ØØØØØØ5590.453124  -ØØØØØØØØØØ.443405150   Ø.267151828

   PREVIOUS RANGE         TIME DELAY          GAIN
ØØØØØØ2300.Ø15624   ØØØØØØ5.705032348   Ø.ØØØØ36734
```

```
 00.  TOP  BOTTOM  CYCLES  VECTOR
        X.     X.     00.     0.

    PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000000000.000000   0000000000.000000000   0.000000000

   PREVIOUS RANGE          TIME DELAY          GAIN
0000000000.000000  -0000065.638305664   0.000000000


 00.  TOP  BOTTOM  CYCLES  VECTOR
        0.     3.    -01.     0.

    PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000001497.734374   -000000434.742324828   0.997170212

   PREVIOUS RANGE          TIME DELAY          GAIN
0000002400.000000   0000001.608779906   0.000326328


 00.  TOP  BOTTOM  CYCLES  VECTOR
        0.     3.     00.     1.

    PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000001501.742186   -000000153.699325560   0.994506968

   PREVIOUS RANGE          TIME DELAY          GAIN
0000002400.003906   0000001.615661620   0.000368718


 00.  TOP  BOTTOM  CYCLES  VECTOR
        0.     4.     00.     0.

    PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000005076.828124   -0000000000.518081664   0.294179386

   PREVIOUS RANGE          TIME DELAY          GAIN
0000002400.007812   0000005.402435302   0.000038760


 00.  TOP  BOTTOM  CYCLES  VECTOR
        0.     4.     01.     0.

    PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000005315.062500   -0000000000.490722656   0.280993782

   PREVIOUS RANGE          TIME DELAY          GAIN
0000002400.011718   0000005.658874510   0.000037026


 00.  TOP  BOTTOM  CYCLES  VECTOR
        0.     4.     01.     1.

    PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000005136.187500   -0000000000.510971068   0.290779576

   PREVIOUS RANGE          TIME DELAY          GAIN
0000002400.007812   0000005.466552734   0.000038314
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 00.  TOP  BOTTOM  CYCLES  VECTOR
       0.     4.     02.     0.

    PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000009968.507812  -0000000000.246353148   0.149821800

   PREVIOUS RANGE          TIME DELAY            GAIN
0000002400.003906   0000010.609802246   0.000006248


 00.  TOP  BOTTOM  CYCLES  VECTOR
       0.     4.     02.     1.

    PREVIOUS Z          PREVIOUS DERIVATIVE    SIN(ANGLE)
0000005374.664062  -0000000000.484344482   0.277877436

   PREVIOUS RANGE          TIME DELAY            GAIN
0000002400.007812   0000005.723266600   0.000036616
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